UNITED STATES DEPARTMENT OF COMMERCE PUBLICATION

NBS SPECIAL PUBLICATION 334

Industrialized Building In the Soviet Union

U.S. DEPARTMENT OF COMMERCE

National Bureau of Standards

UNITED STATES DEPARTMENT OF COMMERCE • Maurice H. Stans, *Secretary*
NATIONAL BUREAU OF STANDARDS • Lewis M. Branscomb, *Director*

Industrialized Building in the Soviet Union

(A Report of the U.S. Delegation to the U.S.S.R.)

James R. Wright, Editor

Building Research Division
Institute for Applied Technology
National Bureau of Standards
Washington, D.C. 20234

National Bureau of Standards Special Publication 334
Nat. Bur. Stand. (U.S.), Spec. Publ. 334, 81 pages (December 1970)
CODEN: XNBSA

Issued May 1971

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402
(Order by SD Catalog No. C13.10:334), Price 75 cents

Key words Building economics; building systems; construction industry; housing; precast concrete; production capacity; production management; production methods; standardization; United Soviet Socialist Republics

Abstract The 1969 Exchange delegation to the USSR reports the status of Soviet building industrialization, with emphasis on Soviet housing. The report describes the State management hierarchy, production of precast concrete components and housing construction procedures. The loadbearing panel system, the mainstay of Soviet prefabricated housing, is compared with the newer three-dimensional box system. Detailed analysis is made of the cost of a nine-story panel prefabricated apartment building in the USSR, and the cost of the same building if constructed in the U.S.

Library of Congress Catalog Card Number 79-607803

Members of the U.S. Delegation	Dr. James R. Wright
	David Watstein
	W. Burr Bennett, Jr.
	Philip D. Bush
	William W. Caudill
	Charles C. Law, Jr.
	Fred W. Mast
	Dr. Charles J. Orlebeke

Contents

Contents continued

Tables

Illustrations

Illustrations continued

Preface

This report is both an amalgamation and a synthesis of eight reports—one from each member of the American delegation which traveled to the USSR August 23-September 9, 1969, to examine Soviet management, planning, design, production and construction practices.

The US/USSR Exchanges Agreement under which we traveled stipulated that emphasis be placed on the "industrialization of the building process." The Building Research Division of the National Bureau of Standards' Institute for Applied Technology, which along with the Department of State sponsored the exchange program, was especially interested in Soviet methods of evaluating innovations in building processes and products. This interest was shared by the delegation members who represent a wide range of US building industry sectors.

Because trends in the United States appear inclined toward greater use of industrialized techniques, the US delegation was most eager to learn of the experiences of a nation whose preeminence in industrialized building techniques is readily acknowledged.

Our itinerary, while structured to provide a general overview of Russian building practices, was arranged primarily to yield an understanding of the industrialized procedures employed by the Soviets in answering very heavy shelter demands.

We took to the USSR a set of pre-formed questions, responses to which form much of the raw material of this report. Once inside the USSR, however, we found that the vast differences between the US and USSR systems rendered some of these questions irrelevant. Also, some of the questions were simply not answered or not answered amply. Finally, there was a communication problem: Virtually all of what we learned was conveyed through verbal translation; the possibility of error or distortion creeping into the translation process was always present.

Our visit was made easier by the advance preparation we received from the Department of State. We are indebted to State—particularly to Mr. Franz H. Misch, foreign affairs officer in the Office of Soviet and Eastern European Affairs—for assistance both in our Soviet visit and in the preparation of this report.

The Exchanges Agreement also provided for a tour of the US building industry by a Soviet delegation. This tour was made September 29-October 16, 1969.

Dr. James R. Wright
Chairman

Foreword

The original reports of the eight American delegates to the Soviet Union were brought together in a limited circulation National Bureau of Standards publication titled *Report of the US Delegation to the Soviet Union*. This book is an edited version of that document.

Structuring the 320 pages of data in these eight accounts into a single monograph has been strenuous, but most enjoyable. I hope the result is fair to the original feelings and opinions of the eight delegates. I have learned from them the difficulty of viewing effectively another culture from the outside, with another language.

All the delegate accounts contain rich observations. Without diminishing the value of any, I single out two upon which this book chiefly rests: the in-depth plant production, construction and economic analyses by Philip D. Bush, and the account containing numerous direct Soviet quotations by William W. Caudill. In addition to these, W. Burr Bennett, Jr., reported on precasting and modular coordination, Charles C. Law, Jr., reported on Soviet utility systems, Fred W. Mast commented on construction management, and Charles J. Orlebeke appraised the evaluation of user needs. David Watstein, in addition to important comments on structural design practice, served as interpreter. James R. Wright guided the delegation as chairman, and reported concerning Soviet practice in standards and research. His work is amplified by E. O. Pfrang, whose independent report from an earlier visit to the USSR is included in the section on research.

I thank especially Neil Gallagher and Barbara Steele who edited the NBS report, James Haecker, Chief, Scientific and Professional Liaison, Building Research Division, and finally, Dr. James R. Wright, Chief, Building Research Division, National Bureau of Standards.

Chalmers G. Long, Jr.
Assistant Professor
School of Architecture
Rice University

Part One
Background

The Technical Exchange Program

Eight Americans traveled to Russia 23 August to 9 September 1969 for a firsthand look at the industrialized building industry of the Soviet Union. Each was expert in some area of construction. The group traveled as official representative of the United States under the US/USSR Exchanges Agreement for 1968-69 which is administered by the Department of State. The Building Research Division of the National Bureau of Standards, US Department of Commerce, was the American sponsor to the exchange. This report documents the findings of the United States delegation.

The exchange agreement prescribed that emphasis be on the industrialization of the building process. The Soviet construction industry is rich ground for this study; it is generally recognized as preeminent in the extent to which building industrialization has been accomplished. Industrialization is a timely subject for the US construction industry. Although there is a trend in the US toward greater industrialization of the building process, progress is not fast enough to meet increasing pressures for cheaper and faster construction—especially in housing.

For purposes of definition, *industrialization* is considered as: mechanization; plant prefabrication; standardization for production line efficiency; and market aggregation for steady year round production and employment.

The itinerary was structured for an overview of Soviet design, planning, and construction practice, and for a specific study of plant prefabrication and construction procedures for housing. The detailed US itinerary to the Soviet Union is listed in the next section. The Soviet itinerary below is summarized by an exchange planning document prepared by the National Bureau of Standards in September 1969.

> The first two days have been designed to acquaint the delegates with the officials of the Department of Commerce and the Department of Housing and Urban Development. During this period there will be the opportunity to visit a new town, large residential construction activities, and an industries

product development program.

On the third day of the program, the delegates will be given a daylight flight from Washington, D. C., on the Atlantic Coast to San Francisco, California, on the Pacific Coast and a free day in San Francisco. While in the San Francisco Bay area, the delegates will see academic and research facilities at the University of California and construction sites at Oakland. They will hear how systems design is applied and see a rapid transit system under construction.

In the greater Chicago area, the itinerary includes Forest Products research and fabrication of both industrial and residential construction. Also included in this general area are roofing installation and nonprofit research laboratories for product improvement and a voluntary system of production quality control.

In the Texas area both academic and research laboratories, and large scale construction sites will be visited.

Upon returning to the Washington, D. C. area, the delegates will devote a one-day trip to York, Pennsylvania, for the purpose of seeing the productions of mechanical systems of buildings. This itinerary was designed to show the delegates a wide range of climatic conditions and various urban environments.

Members of the U. S. Delegation

Delegate	Organization	Position	Areas of Responsibility
Dr. James R. Wright (Chairman)	National Bureau of Standards Department of Commerce Washington, D.C.	Chief Building Research Division, Institute for Applied Technology	building research management; organic building materials; building standards

Delegate	Organization	Position	Areas of Responsibility
David Watstein (Interpreter)	Structural Clay Products Institute McLean, Virginia	Manager, Structural Research	masonry and clay tile; reinforced concrete; structural engineering
W. Burr Bennett, Jr.	Prestressed Concrete Inst. Chicago, Illinois	Executive Director	cement and concrete; modular coordination; building systems
Philip D. Bush	Kaiser Engineers Oakland, California	Vice President	industrial engineering; metallic building materials; industrialized building (housing)
William W. Caudill	Caudill, Rowlett, Scott Houston, Texas	Principal (Partner)	architecture; design; computers; building systems
Charles C. Law, Jr.	Public Buildings Service General Services Admin. Washington, D.C.	Chief, Technical Services Branch, Design Services Div., Off. of Design and Construction	mechanical engineering; mechanical systems (heating, air conditioning, plumbing); acoustics
Fred W. Mast	Jens Olesen & Sons Construction Co. Waterloo, Iowa	President (immediate Past President of the Associated General Contractors of America)	general contracting
Dr. Charles J. Orlebeke	Department of Housing and Urban Development Washington, D.C.	Executive Assistant to Secretary Romney	urban building technology; human factors; labor

The US Delegation: Charles J. Orlebeke, Fred W. Mast, W. Burr Bennett, James R. Wright, William W. Caudill, Philip D. Bush, David Watstein, and Charles C. Law, Jr.

Itinerary

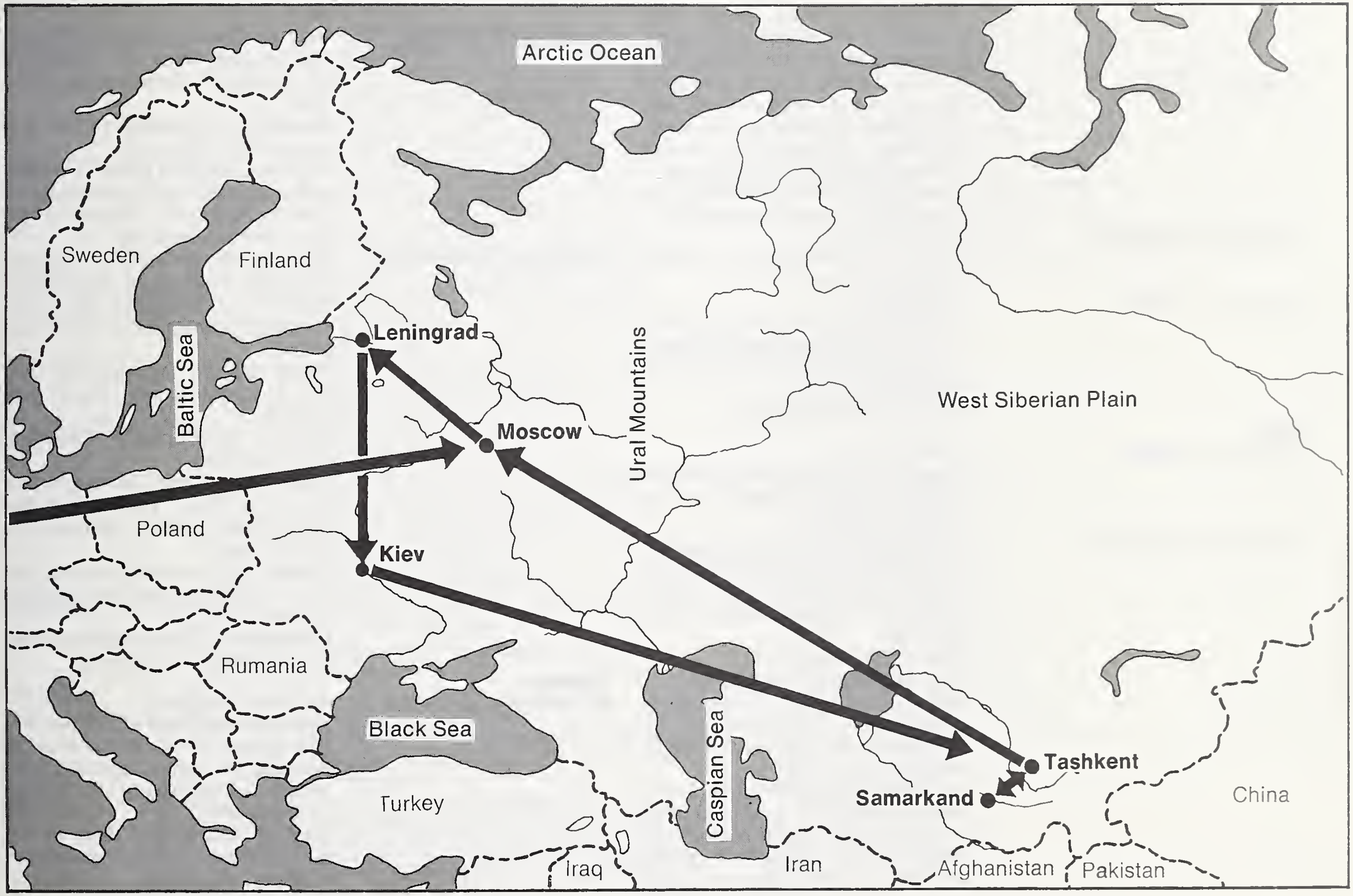
Moscow

August 23, Saturday	Evening arrival in Moscow Meeting at the airport
August 24, Sunday	Sightseeing
August 25, Monday	Discussion at the Gosstroy of the U.S.S.R. Clarification of the program Visit to Gosgrazhdanstroy (Public Buildings Construction)
August 26, Tuesday	Discussions at Glavmosstroy (Moscow Municipal Construction) Visit to Lenin Mausoleum Visit to new public building sites Discussions at Tzniepzhilishcha (Central Research Institute for Economic Planning of Housing Construction)
August 27, Wednesday	Discussion at Glavmospromstroymaterial (Moscow Directorate of Structural Materials Industries) Visit to Precast Reinforced Concrete Plant No. 9 (D.S.K. No. 9) Visit to Architectural Millwork Plant Visit to Permanent Building Material and Building Elements Exhibit Departure for Leningrad by train "Red Arrow"

Leningrad

August 28, Thursday	Arrival in Leningrad Discussions at Glavleningradstroy (Directorate, Leningrad Municipal Construction) Visit to construction sites Discussions at Glavzapstroy

USSR



Arctic Ocean
Sweden
Finland
Baltic Sea
Leningrad
Moscow
Ural Mountains
West Siberian Plain
Poland
Kiev
Rumania
Black Sea
Caspian Sea
Turkey
Iraq
Iran
Afghanistan
Pakistan
China
Tashkent
Samarkand

	(Directorate, North West Construction, includes Leningrad, Novgorod and Pskov regions)
August 29, Friday	Visit to D.S.K. No. 2 (Housing Construction Combine No. 2) and Automated Dispatching Service Discussion of design of standardized buildings at Lenzniiep (Leningrad Central Research Institute for Economic Planning)
August 30, Saturday	Sightseeing Visit to Petrodvoretz (Peter's Place) Hermitage
August 31, Sunday	Sightseeing Visit to Pushkin (Katherine's Palace) and Pavlovsk (Paul's Palace) Luncheon with Palace guides in staff dining room Departure for Kiev by air
Kiev August 31, Sunday	Arrival in Kiev Meeting with Ukrainian hosts in Borispol' Airport waiting room to confirm program
September 1, Monday	Discussion at Ukrainian Gosstroy led by Chairman of Gosstroy, M. I. Burka on problems of planning, design and organization of construction Visit to Glavkievgorstroy (Kiev Municipal Construction) Visit to D.S.K. No. 3 (Building) Construction Combine No. 3) Inspection of plant and automatic dispatching service Visit to Plant Construction Combine of Ministry of Industrial Construction at Brovary (Brewertown) Inspection of Russanov Housing Complex (construction in progress)
September 2, Tuesday	Visit to Construction and Building Erecting Trust No. 1, Ministry of Industrial Construction Ukr. SSR Inspection of Diamond Plant and garage for 1200 cars Visit of Collective Farm "Kodaki" and inspection of its construction Visit to Pioneers' Children's Palace, and sightseeing
September 3, Wednesday	Discussions at NIIASS (Science Research Institute for Automated Systems of Planning and Construction Management Ukr. Gosstroy) Inspection of Experimental 3-D Block Construction (room size blocks) Visit to St. Sophia's Cathedral (XIth Century) Visit to Kiev Cave Monastery and Kiev City Park. Visit to Golden Gate (10th century entrance to city of Kiev) Dinner and reception honoring the U.S. Delegation by Gosstroy of Ukr. SSR Departure for Kiev Airport (Borispol') for flight to Tashkent
Tashkent September 4, Thursday	Arrival in Tashkent Meeting with hosts in Tashkent Discussion of industrialization of housing and public building construction, Gosstroy of Uzbek SSR (Uzbekistan) Visit to GlavAPU (Chief Architect's Office) and Tashguiprogor Institute (Tashkent Institute for

	Design of City); discussion with Chief City Architect of planning and construction problems and their solutions for housing and public buildings construction in Tashkent. Inspection of new residential construction
September 5, Friday	Discussion at Glavtashkentstroy (Directorate, Tashkent Municipal Construction) of application of large precast panels and panel frame construction in Tashkent
	Visit to Tashkent D.S.K. No. 1
	Inspection of new construction designed for severe local seismic conditions
	Visit to Uzbek Khanza Theater to view play based on life of Uzbek national hero Ulugbek
September 6, Saturday	Departure for airport for flight to Samarkand
	Entire day spent in Samarkand viewing historical and architectural monuments of the city
	Departure for airport and return flight to Tashkent
	Arrival in Tashkent
September 7, Sunday	Farewell breakfast with hosts in city of Tashkent
	Departure for airport and flight to Moscow

Moscow

September 7, Sunday	Arrival in Moscow
	Attend performance at Bolshoi Theater (opera—Marriage of Figaro)
September 8, Monday	Visit to NIIZhB and NIISK (Institutes for Concrete and Reinforced Concrete and for Building Constructions). The latter Institute includes the Soviet Masonry Research Laboratory
	Final visit and discussion with hosts at Gosstroy of USSR
	Reception and dinner honoring US Delegation by Gosstroy of USSR at Moscow suburban resort, "Beryozki."
September 9, Tuesday	Exit interview at US Embassy with Charge d'Affairs
	Depart for Moscow airport (Sheremetyevo) and flight to Paris


Exchange Hospitality: Lavish Russian Luncheons

Part Two
The Soviet Union and Industrialization

Commitment

TABLE 1. USSR HOUSING PRODUCTION	1964	1965	1966	1967	1968	1969 Est.
GOVERNMENT & COOPERATIVE	58.9	63.2	65.9	68.7	69.3	71.8
BUILDING AT "PRIVATE" EXPENSE	16.2	16.1	15.9	15.6	14.2	31.2
COLLECTIVE FARMS & FARMERS	17.6	18.3	20.3	20.2	18.6	
TOTAL	92.7	97.6	102.1	104.5	102.1	103.0

SOURCE: USSR Gosstroy 8 September 1969
Units: Million square meters useful living space (net apartment area)

The Leap to Industrialization

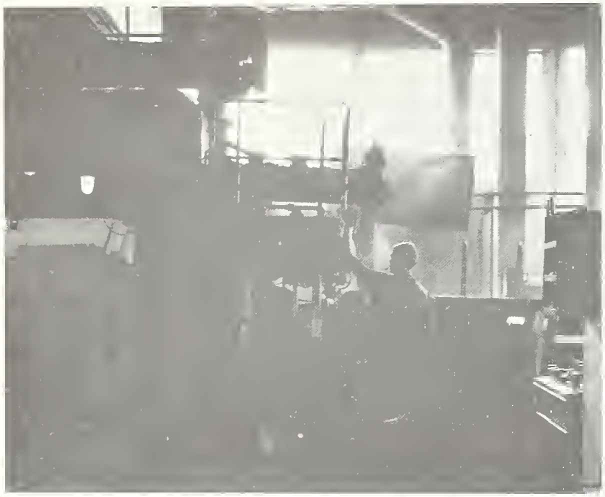
In 1946 much of the Soviet Union lay in ashes; World War II had destroyed 40% of her housing, and her economy was seriously crippled. The trend to urbanization in the USSR as in all the West was well established before the war; after, it was accelerated. In 1917 urban inhabitants in the Soviet Union were only 18% of the total population; today they comprise 62%. Traditional justifications for industrialization of the building industry were omnipresent in the post war years: There had been few craftsmen in the building industry before the war; there were fewer after. The total labor pool was seriously depleted; time was precious. The demand for new construction, especially housing, was immediate. Of most consequence, the market was totally controlled: the buyer, producer, and seller were one in the State. The *need* forced the leap to industrialization.

The Housing Record

The USSR has made a major continuing commitment to housing: the State has assumed responsibility for the provision of an apartment for every citizen. The Soviet five-year plans are perhaps familiar enough to the average American to constitute a cliché, but they are in fact real. The planning share for housing construction fluctuates with the rise and fall of the pulling power of the major claimants for capital funds: heavy industry, the military, and high priority scientific research. But the record speaks for itself: the USSR has given high priority to housing. The 1968 construction figure from Table 1 of 102,100,000 m^2 useful living space or net apartment area equates to 128,000,000 gross building area at 80% efficiency. This equals 1.4 billion ft^2; the US built 1.5 billion ft^2 for the same year.

The state owns all land, but not all houses. Table 1 lists an interesting housing category "at private expense." This means individuals may build single-family dwelling units, or a cooperative of several individuals may own a small apartment house. There are the usual restrictions to height and area, but allowed space per person is greater than that for government housing.

The majority of new housing is industrialized. Production plants work sometimes around the clock turning out prefabricated compo-



Moscow: Bi-level Conveyor, End Elevator to Curing Tunnel

nents for standardized building systems; and erection crews work a three-shift day constructing them. With increasing frequency, plant management and construction management are one; "turn-key" responsibility is not atypical. The only limits to total industrialization goals are the rapidity with which new factories can be built and the limiting transportation radii from the plants.

Justification for Industrialization

For industrial, commercial, and community building, prefabrication is common and increasing, but does not approach the intensity or extent of industrialization for housing. Construction procedures for building categories other than housing are similar to those of the United States, but Soviet construction of housing differs radically. For these reasons, major emphasis in this report will be given to housing. The success of the postwar venture in Soviet industrialized housing is indeed impressive. The US delegation was briefed repeatedly on the justifications for the leap to industrialization; the claims are compelling in comparison with conventional construction:

40-50% less labor consumption.
30-45% less construction time.
Year round construction.
Overall cost savings of 5-20%
Higher quality construction.

Yet in a new world of concrete, the Soviet respect for old brick is appealing. As proud as a Russian may be of his country's massive commitment to new housing, he retains a strong feeling approaching reverence for old structures. The Soviets give careful attention to the preservation of old buildings and old cities. This is particularly evident in Leningrad and Kiev; older sections of these two cities are restored much as they were in the last century. Where renovations are necessary, the buildings are gutted of their internal wood structures and replaced with concrete floors to eliminate fire hazard; the original facades are protected. When new governmental buildings, hotels, office buildings and the like are required within an old inner city, they are classified "unique buildings" and are custom designed. As one official put it, "We would never put one of the dull standards houses in the middle of our beautiful city."

Public Housing in Moscow: City Agency Selects Tenants

User Needs Determination

It is often hard to gauge the fitness of dwelling places to the life-style needs of another culture; this report is a case in point.

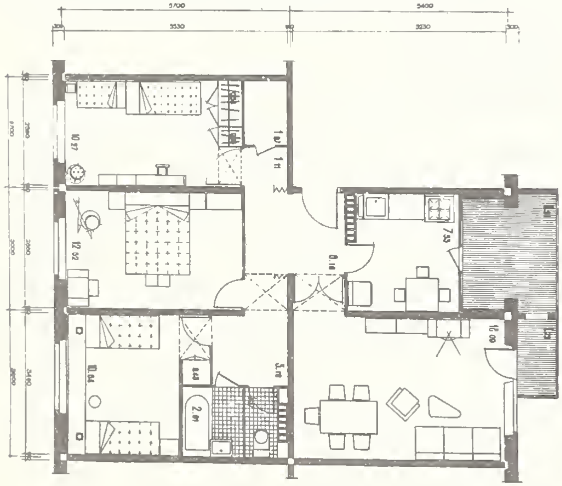
In each city visited, the US delegation inquired as to the specific methods used to obtain the opinions of Soviet citizens regarding housing design improvements. In Moscow, officials of the Central Research Institute for Economic Planning of Housing Construction gave two such methods: personal interviews and mailed questionnaires. Students conduct fifty thousand tenant interviews each year on all aspects of housing; in addition, one hundred thousand questionnaires are distributed annually with similar questions. The results are computer-analyzed for use in future planning for housing.

In Leningrad, students poll each summer some one hundred thousand families for user needs. The results are recorded for planning, and for understanding trends over the years in tenant needs and wants. One questionnaire used by the Leningrad Zonal Scientific Research and Design Institute for Standard and Experimental Design of Public and Residential Buildings, dated 1966, is very interesting in signalling the probable use of such information. The cover note on the questionnaire reads as follows:

> Dear Comrade,
> Improvement of living conditions in the extreme north regions is one of the most important problems facing us in the next few years. To solve this problem, we have to build many new residential and public buildings which would satisfy the working, living, and recreational requirements of the Northern towns and settlements. The attached questionnaire is designed to reveal these requirements. Information obtained from the questionnaire will be used to help architects and engineers consider more thoroughly the needs of the population, and to design dwelling houses, nurseries. schools, public buildings, and towns and settlements of the North in a way best satisfying the needs of the Northerners concerning their housing and everyday services, cultural and instructive


Moscow Apartments: An Average Rental Is $6 Per Month

Typical Apartment House Floor Plan



activities, sports and peaceful relaxation.

Then follow 33 questions. There is not a single question about any physical feature of living units. There is no place to register views on space quantity or allocation, on kitchens, bathrooms, or storage. The questions that are included reveal a curiosity about the respondent's total life style—the way he spends his time, and the way he would like to spend his time. There are questions about time taken for studying, attendance at theater, concert, night clubs and restaurants, sports participation, hobbies, and social work. In each case there is a comparison question on how much time the respondent would like to spend if circumstances permitted. The respondent is asked what months of the year he considers desirable for various kinds of outdoor sports, swimming, tennis, volleyball, skating, hockey, and for walks and picnics. One of the questions is "Where do you usually take your children out for a walk when the weather permits?"

The fact that there are no questions at all bearing on the dwelling unit itself suggests the possibility that the apartment is looked upon as a rather incidental part of the family's total living experience. The questionnaire is obviously of more value for planning than for revisions in design of standard high-rise apartments.

It is of course risky to speculate too long on the basis of a single questionnaire, but the dwelling unit may well be but a utilitarian necessity for the family, one which fades in importance against the social and communal life of the family outside the home. The comments below are of interest in this context.

Life Style

The US delegation visited two apartments in a four-year-old five-story walk-up in Moscow. Both could be called typical Russian apartments. The family of a professor lives in one apartment; the family of a factory worker lives in the other.

There are four in the professor's family. His wife woks, as do most Soviet wives—57% of Moscow's *total* population works. The family is allotted an apartment of 580 ft^2: one bedroom with twin beds, one living room with a foldaway bed for an adult son, a bedroom-den where the teenage daughter studies and sleeps,

a kitchen, a bathroom, and a balcony. The professor's salary is approximately $300 per month, and his wife's salary is approximately $150 per month, both much higher than the average.

The factory worker's wife works also. They have one less child and one less room than the professor's family. His salary is $120 per month, his wife's approximately $80 per month, both about average.

In this apartment complex, as in all others, there is no preference or distinction as to location of tenants or of apartment amenities. The professor, factory worker, and even plant manager may have identical apartments next to one another.

The size of a family determines the size of the apartment. The apartments are spotless and the grounds trash-free and simply landscaped, although lawns were not well maintained—an observation applicable to most places visited.

When a new apartment building or "house" is completed the new tenants are selected by a city agency. Some will come from waiting lists for larger apartments or waiting lists for change in location, some will move when their plant moves, and still others will come from older buildings to be demolished in another section of the city. No one moves or even trades apartments privately without the approval of the city government. After move-in, tenants form a group with elected leaders to negotiate changes with the city and to accomplish whatever self-government is necessary for tenant needs. The city is usually responsible for maintenance; janitors, gardeners, and maintenance people are assigned by the city to the new apartment.

A family of four can rent an apartment for six dollars a month. Electricity is metered, and gas, water, and hot water for heating are charged prorata for the entire building; as an average, utilities amount to another six dollars per month. Based on a typical monthly wage of $120, the rent amounts to 5% of the total income and utilities another 5%. Since most wives work, however, the real percentage is even lower. Rent covers approximately half the maintenance and operating cost of the building; it does not touch the construction cost. USSR theory holds that it is the state's responsibility to house its citizens.

Seventeen-story House Under Construction In Kiev

The Size of an Apartment

The Soviets use a term "net living space" which refers only to the area of the living room and the bedrooms. In the years between 1923 and 1950 the average urban per capita net living space in the USSR fell from 6.45 m^2 to 4.67 m^2. The most compelling postwar consumer need was a place to live. Population growth, the migration of population from rural to urban areas, decades of neglect of housing needs by Soviet political leadership, and World War II all combined to produce by 1950 very nearly intolerable conditions of overcrowding, poor sanitation, and increasingly rapid deterioration.

The State answer to this mammoth dilemma is industrialization —industrialization for the construction of multistory apartment buildings. In a massive building program, the USSR raised that 1950 figure of 4.67 m^2 to a national average for every inhabitant of 5.3 m^2 in 1957 and 7.4 m^2 in 1969. The leap is indeed impressive. The Soviet nation is well on its way to meeting a goal of an apartment for every family.

The housing task is admittedly incomplete. A newly-married young couple still finds it necessary to live with in-laws for a year or more before their turn on the waiting list yields an apartment. The 7.5 m^2 figure, impressive as a reference mark for rate of change, is still below the new construction norm of 9 m^2, and way below the Soviet end goal of 15 m^2 for every person.

The term "net living space" to which the above figures refer is not common to American usage; it includes only the living room and bedrooms. As of 1 January 1970 the term was abandoned in favor of "useful living space" which includes living room, bed rooms, entry hall, kitchen, and bathroom. Care must be taken to keep in mind which term is referenced in the tables of this report. The 9 m^2 *net* per person equates approximately to 560 ft^2 *useful* for a family of four, and the 15 m^2 net equates to 940 ft^2 useful for the same family. As a point of reference the 9 m^2 standard is roughly equal to the nominal minimum US Housing Assistance Administration public housing standard, 60% of the maximum standard. The quality and amenities of the USSR apartment, however, are below HAA standards. These comparisons are more

fully developed in the final chapter.

The Rebuilding of Tashkent

Tashkent, fourth largest of the Soviet cities, demonstrates Russian resolve and the potential for the industrialization of housing. In 1966 an earthquake nearly demolished this city of 1,100,000 in Uzbek Republic. One-third of the total living area was destroyed and another one-sixth was damaged to an extent requiring demolition. The earthquake destroyed 96,000 apartments, 225 nurseries, 181 schools, and 118 medical facilities. Out of this rubble, Tashkent has rebuilt 23,000,000 ft^2 of housing and 15 schools in the last two years.

Before the earthquake, most of the houses were old and of one-story masonry-and-frame adobe-and-straw construction. These buildings constructed before the earthquake which met the seismic code specifications stood; most others cracked and fell. Russian seismic intensity nine is approximately equal to Mercali scale in number and is equivalent to Richter zone twelve. Before the earthquake, standards called for seismic intensity eight; after the earthquake they were raised to nine but no changes were required in structural detail.

The rebirth from the earthquake was made possible by considerable aid from other republics. The republics sent trainloads of people, equipment, and precast concrete; each of the major republics took responsibility for the rebuilding of a specific area of the city. Industrialization counted heavily in the rebuilding. Panel type prefabrication alone accounts for 60% of the new housing and 70% of the schools. Tashkent targets 1981 for total prefabrication of all new apartments, schools, nurseries, and factories.

Because of the emergency and because of the extreme Tashkent desert temperatures the builders were innovators . . . . and perhaps because they were away from home. Balconies were made larger for sleeping. One new apartment block has an inner court arrangement similar to patios. Glass folding-doors open entire living room walls to balconies. Windows are door size to facilitate cross ventilation. Ceiling heights for a hot country are raised from 8′-5″ to 9′4″. Some apartments without cross ventilation receive cold air pumped from a central chilling plant; some have chilled water in the floor/ceiling slab radiant heating pipes.

The net living space in Tashkent is 6 m^2 per person, lower than the 7-9 m^2 in other major USSR cities, but each resident is housed only three years after the devastating earthquake.

Part Three
Organization for Construction

The Management Hierarchy

Gosstroy

Gosstroy stands for State Construction committee: there are the USSR Gosstroy, republic gosstroys, and big city gosstroys. These people are responsible for all construction in the Soviet Union. They do not build a neat pyramid of authority—large cities make decisions for republic sized regions and not all republics have gosstroys. USSR Gosstroy employs 54,000 people including 8,000 scientists, 34,000 technicians, and 10,000 experimental plant workers. The lesser gosstroys employ an additional 180,000 people; this is no mean set of bureaucracies.

USSR Gosstroy touches all Soviet construction: buildings, roads, industry, dams, pipelines, etc., but only approves projects; industry must obtain financing for the projects from the State Construction Bank. USSR Gosstroy develops new designs, sets standards, conducts research, approves projects and building procedures, and coordinates cooperative exchanges. USSR Gosstroy determines what materials and machines will be necessary to carry out the USSR five year plan and advises the production ministries so that they in turn will build the capacity to meet the plan. USSR Gosstroy approves projects, but project location and administration is the business of republic or city gosstroy planning agencies.

Gosgrazhdanstroy, a division within USSR Gostroy for Civil Construction and Architecture, works specifically with building construction: general planning, research, and actual building design. Most of the standard building systems and designs for "unique" buildings comes from this division at the top. USSR Gosgrazhdanstroy like USSR Gosstroy has its subordinate parallel at republic and city levels.

The Lesser Gosstroy

The Ukraine Gosstroy is a typical republic gosstroy. It is responsible for regional, city, and detailed site planning in the Ukraine Republic, and, of interest to this report, for construction administration of some 500,000 apartments annually including 22,000 in Kiev alone. Ukraine Gosstroy prepares construction documents from standard USSR Gosstroy building series designs, then contracts for construction with the production factories and erectors directly, or through local city agencies. If code problems arise

they are referred to USSR Gosstroy unless they are strictly of local concern, in which case they are decided by Ukraine Gosstroy. Glavleningradstroy, the Gosstroy for Leningrad, is typical for large cities. With a force of 60,000 people, it reports to the Leningrad City Council, and is responsible for planning in a region to the north as well as in the city proper. The differences between large city gosstroys and republic gosstroys are not precise; they share similar responsibilities.

Cost Control and Construction Management

The production factories and erectors contract with the gosstroy to make the products or build a structure for an agreed price. Apparently, normal practice is to set estimated costs about 12-15% above current costs. The inevitable profit is returned partly to the State and partly to the factory or erector for additional employee benefits such as bonuses, an expanded nursery for the children of women workers, or additional amenities at the vacation resort which the factory may own. In the event of a construction casualty such as fire or failure of some structural element, additional financial support is available.

Cost controls are based primarily on this system of bonuses which extends to all workers in an organization. Very extensive production records are easily quoted, but it is not readily apparent how they are used to locate operational weaknesses. One of the most difficult problems is the fact that workers in construction are not paid as highly as workers in the precasting plants—the highly skilled leave the field for the factory.

Gosstroy is using two management systems for urban housing construction, trusts and combines. Trusts are construction organizations or firms which may be either general or subcontractors—building trusts or specialized trusts. The building trusts perform the general trades work on the superstructure only and the specialized trusts perform the balance of the work including site work, the foundations, the plumbing, the electrical work, and the painting. A newer and preferred form of organization is the combine: a combine of precast plant production and building trust under one management; of factory and erector in "turnkey operations." Under either system, about 10% of the total personnel is in management and supervisory positions. Most of the construction machinery is owned by several special machinery trusts and rented to the building trust or combine requiring its use. The specialized trusts act as subcontractors to the combines when the latter have turnkey contracts.

Building Standards and Research

A National Code

The terms "building standards" or "norms" are used in the Soviet Union rather than the term "building codes." In the Soviet system a standard once adopted has the force of government behind it and is comparable to a USA building code as promulgated by a state, county, or municipality.

Standards are developed under the same vertical structure that exists for research and most other functions; at the national level these are the responsibility of USSR Gosstroy. USSR Gosstroy standards are mandatory throughout the Soviet Union. Consideration is given of course to differences in the major geographic zones.

Development of new standards involves all of the construction industry. Discussions with Gosstroy officials indicate that new standards are developed by Gosstroy and sent down to the republics and cities for additional technical detail. Discussions with the republics, however, indicate that standards are frequently initiated at the local level and are adopted at successively higher levels, becoming mandatory at each level. Probably, the overwhelming trend is from the top down.

A consensus principle is used in the development of new standards by USSR Gosstroy. The Concrete and Reinforced Concrete Institute, for example, may develop a new standard for USSR Gosstroy. It will provide technical data and draft the standard; expert consultants may be used. The draft will then be reviewed by all users: the factories, ministries, and republic gosstroys.

Before the proposal is received by USSR Gosstroy all negatives must be resolved or at least clarified. Only then, with all reservations surfaced and addressed, will the draft come before USSR Gosstroy for action. Hopefully, the standards adopted will represent industry consensus.

According to Moscow Gosstroy, building changes are relatively easy to make at the local level, with USSR Gosstroy's approval; sometimes a standard can be revised by phone—the only constraint is technical complexity. Leningrad Combine DSK-2 has

another story: it requires fourteen months to make a change in the standard for an apartment stairway; the technical retooling in the factory requires but five months of this period.

Gosstroy standards are minimum standards; if an industry due to the nature of its work has special requirements which are more rigorous than those of Gosstroy, these may be imposed over the minimum standards.

It is evident that an intimate and continuous liaison is maintained between the construction industry and the organizations responsible for carrying out evaluation tests and development of standards. The USSR looks like a nation of innovators; worthwhile ideas coming either from industry or laboratories are thoroughly evaluated in generously staffed research institutes.

Gosstroy and the Research Institutes

Building research in the Soviet Union reflects the same degree of centralization and vertical structuring as do all other major functions; research pertaining to building construction comes under Gosstroy, the State Committee for Construction Affairs for the USSR. USSR Gosstroy has under it, at the federal level, a number of research institutes, each highly specialized; most fundamental research is carried out at this level.

The gosstroys of the individual republics also contain within them research institutes, but their work is primarily in applied research, development, and technical service to factories; their facilities are less elaborate. Laboratories within precasting plants and city construction departments are largely for production control. Each laboratory depends on the larger, more basic laboratory of the next higher governmental unit for support. For example, the Uzbek Republic, where seismic problems are most severe, has its own seismic laboratory, but the most fundamental research and the most elaborate facilities for seismic research are in Moscow in the Institute for Structural Design. Of course, the two laboratories coordinate their work with each other.

The research institutes are closely related to the universities. Members of the institutes may hold university chairs. There exist also close ties between the institutes and the Soviet Academy of Sciences. The institute system appears sufficiently flexible to bring experts together from organizations outside a given institute to work on specific programs; the use of consultants is apparently a common practice.

The institutes are large, with perhaps over a thousand people each, but it must be remembered that this represents the entire research effort of the USSR. There is no private industry with its own in-house research activity. Government sponsored research is equal to total research in any given field.

Dr. E. O. Pfrang, Chief, Structures Section, Building Research Division, National Bureau of Standards, visited Moscow in May of 1969. He concentrated more fully on laboratories concerned with building research than did the US delegation. His reports are included within the following paragraphs on research.

The Process for Soviet Research

Three institutes are instructive in generalizing the Soviet research effort: the Research Institute for Concrete and Reinforced Concrete, the Research Institute for Building Structures, and the Central Research Institute of Industrial Buildings, all in Moscow.

Initially the Research Institute for Building Structures was a part of the Research Institute of Concrete and Reinforced Concrete, but the organization became so large that it became advisable to split. Building Structures now numbers 700 employees, and Concrete and Reinforced Concrete 1000. Of these 1000, 400 are professionals including the equivalent of 15 PhD's and 135 Masters.

Funding for the institutes is largely straight from Gosstroy. Concrete and Reinforced Concrete, for instance, has an annual budget of three million rubles, 75% of which comes from Gosstroy, the remainder from production plants requiring research assistance. Research program selection is based on recommendations of the institute staffs and on orders from Gosstroy for specific problems.

The Concrete and Reinforced Concrete Institute, though engaged in basic engineering research, also carries out applied research, product development, and technical service to factory combines. Within the structure of the Institute is a Bureau of Reali-

zation with a staff of 350 people and a budget of one million rubles, roughly one third of the organization. These people introduce laboratory innovations into production practice.

Full scale testing is common to all institutes, and laboratories are well equipped for such work. The Concrete Institute has a complete production scale plant on the premises to manufacture concrete components for testing. The plant has a 150 meter prestressing bed, advanced machines for forming wall panels and slabs, and produces concrete from its own batching plant. The use of full-scale components, buildings, and building complexes is apparently quite common to Soviet research, in contrast to the US practice of laboratory simulation and modeling prior to field test. A case in point is a seismic test planned near Tashkent. Glavtashkentstroy is building a small city of eighty buildings at full scale of all types and heights of construction excluding only sanitary facilities. An earthquake of intensity nine equal to the 1966 Tashkent earthquake will be induced by exploding 2,200 tons of TNT at 250 feet below the surface; the epicenter will be 430 feet from the center of the test city.

In laboratories at all levels, instrumentation is not highly sophisticated—there is a notable lack of electronic data acquisition equipment. Most acquisition and data reduction are apparently carried out by manual methods. For example, the Building Structures Institute conducts a considerable amount of research in structural dynamics. All of this work, however, is done with sinusoidal rather than random load inputs. Data is acquired for these experiments with multichannel recording oscillographs, with data reduction by hand. It appears that there may be more strain gauges than there is analysis.

The Central Research Institute of Industrial Buildings is responsible for standards and systems development for all industrial building types in the USSR. The approximately 1000 employees set detailed programming standards for each industrial type, and design basic structural systems for off-the-shelf planning. Currently, two precast prestressed systems have been developed, one for single story, one for multi-story construction. These are fully developed catalog systems; design is a matter of selecting applicable components.

Considerable pressure is brought to bear on industry to use only these discrete systems, but renegades are not infrequent. Fiat on the Volga and Moskvich in Moscow both rejected catalog design. Their new plants, possibly the two largest projects now under construction in the Soviet Union, are both of steel. In the current five year plan great emphasis is given to light industry: electronics, instruments, and consumer goods. There is some evidence that these industries are demanding a much higher quality building than did the basic industries.

In conclusion, one must be cautious as to an assessment of the total building research effort in the USSR. The term "research" is used extensively and the numbers of staff are very large. But many engineers are not involved in research at all and have no laboratory facility at their disposal. Their concerns are planning, standards, production, and construction. Then too, many laboratory activities are in the area of product and technical service rather than research. A realistic comparison with building research in the USA is difficult if not impossible.

Part Four
Design

Design for Industrialization

The Standardization Approach

The Soviets approach building with a carefully linked process of design, production, and construction. Design is derived as much from a knowledge of the needs of the precaster and erector as it is from the needs of the user. Design for all but the "unique" building is based on sets of coordinated modular dimensions to allow the lowest possible number of system components. To gain maximum plant efficiency, once a system is developed and tested the production run on the system is almost indefinite. Model changes are infrequent, probably on the order of four to ten years for major revisions.

Under the press of economic efficiency, the large majority of Soviet housing systems is closed; there is little or no component interchange from one system to another. Standard design series are simplified to the point of eliminating planning options and systems interchangeability. One official claimed that there are but twelve basic designs for apartment houses in all of the USSR. Typically a combine will be charged with "turnkey" responsibility for the production and erection of a single apartment series model for maximum industrial effectiveness. It is a stock plan: the height is fixed, the plan is fixed, the exterior appearance is fixed. The one variation is the incremental length determined by the number of elevator stair modules. Industrialized building systems, on the other hand, are open systems and offer a great deal of flexibility.

Site planning and design for new systems are both highly centralized. Development work for new systems is done at both USSR and republic gosstroy levels, but all systems must receive USSR Gosstroy's stamp of approval to become new standards, regardless of design origin. Organization for design development is highly conservative; most work is routine adaptation and improvement of existing standards. Site planning and construction documents, worked within the options of the selected system, are the responsibility of republic or city gosstroy. Below this level architects and engineers are employed by the trusts and combines, but only in quality control or decorator capacities.

Soviet Design for Housing

Planning for new housing is generally worked within neighbor-

TABLE 2. APARTMENT HOUSE BASIC INFORMATION

9 STORIES
216 APARTMENTS
6 STAIRCASES
1 ELEVATOR PER STAIRCASE
4 APARTMENTS AROUND EACH STAIRCASE

Apartments	Living Rooms**	People	Net Living Space/Apt.**	Useful Living Space/Apt.***		Ratio Useful/Net Living Space
1	10-12%—24	1-2	16 m^2	32 m^2	350 ft^2	2.0
2	30%—65	3	28-30	48-50	530	1.7
3	48%—103	4-5*	45	64	690	1.4
4	10-12%—24	5-6*	55	72	780	1.3
2.6	100%—216	3.7	38.2	56.9	612	1.49****

SOURCE: Glavleningradstroy Combine No. 2 29 August 1969

* *Occasionally*
** *Includes only living room and bedrooms*
*** *Living room, bedrooms, inside hall, kitchen and bathroom*
**** *Weighted average*

Leningrad: The Bus Service Barn is a "Unique Building"

hood districts. The apartment blocks or "houses" are grouped around nursery, kindergarten, and school; in the best planning tradition, children do not have to cross busy thoroughfares. Stores and service shops are included, sometimes within the ground floor of the houses and sometimes in separate buildings. The Kiev example is illustrative. With a population base of one and a half million, Kiev is constructing fifteen such separate housing districts, each accommodating up to 60,000 people. Three more neighborhood districts will be started shortly.

Two prime planning concerns for the Soviets are light (three hours of sunlight per room at the March solstice), and breathing room. In one of the neighborhood districts constructed by Kiev Combine No. 1 for 40,000 people, buildings will account for 20% and green space for 80% of the total area of 275 acres. Because of this Russian concern for breathing room around every building, and because a whole district may well have but one apartment house design, height, and form, there is a tendency to a certain monumental dullness in the neighborhoods. The problem persists even in the largest districts where as many as three combines may erect three different kinds of apartment blocks.

Most apartment houses are planned with four apartments clustered around each stair-elevator core. Leningrad Combine No. 2 builds nine-story apartment houses with this arrangement. Generally No. 2 builds six staircase sections per house for a total of 216 apartments, with apartments of one, two, three, or four rooms for living and sleeping. Table 2 lists basic information for this apartment series. Combine No. 2 plans soon to go to twelve-story buildings with two elevators per staircase, but for the time being its total output is a single stock nine-story house.

It is readily seen from Table 2 that apartments and the rooms within them are not overly generous. The usual living room is rarely over 10 feet in width; closets are generally wardrobe furniture inside the room. Most complaints, it appears, center on the size of kitchens. One combine, in an attempt to make the kitchen of its standard nine-story house somewhat larger, found room for cutting in the stairwell. The change required fourteen months.

Moscow's Television Center Tower: a "Unique Building"

Gosstroy occasionally looks into the future with full scale prototypes. One such experiment is the "apartment house of the future" or "the house with extensive services" by architect Osterman in Moscow. Gosstroy feels it may be popular fifty years from now. There are two separate apartment buildings approximately 200 feet apart connected by a service wing: nursery, nursery school, laundry, snack bars, and grocery stores. The individual apartments have no kitchens; each apartment floor has a communal kitchen and dining room. Whether this idea for living catches on remains to be seen; the project is just now nearing completion.

The demands of rigid standardization leave the planner few options for innovative design. Industrialization in Russia is first an economical solution to the problems of building shelter, and a certain heavy-handed dullness too often marks the resultant environment. Some of the "unique" buildings occasionally mentioned, however, are quite fine, and the free hand of the designer is evident. The large space structures are particularly suited for showing off the best of industrialization within broader constraints. As consumer demand increases with a maturing economy fully recovered from World War II it is probable that flexibility in model adaptation and interchangeability will permeate the rigid one-model assembly line housing industry.

Modular Coordination

Dimensioning in the USSR is based on the European basic module of IM equal 10 cm, with a preferred series based on 3M or 30 cm increments. Planning modules are generally larger than those used in Europe, usually 3, 6, or 9 meters, or in terms of the basic module 30M, 60M, or 90M. Public buildings are generally laid out on a 30M or 60M planning module; 15M is permitted but not preferred.

Multi-story industrial buildings are designed on a well defined modular standard, with column centers at 6 x 6, 6 x 9, 6 x 12, or 7½ x 9 meter grids. In general the preferred grid is 6 x 6 meters, increased in either direction by multiples of 3M or 30 cm. For one story industrial buildings using prestressed concrete trusses for the main roof members, columns are spaced at 12 meters, with truss spans of 18, 24, and 36 meters. The trusses are planked with 3 x 12 meter precast ribbed roof slabs. All components are

centered on the lines of the modular grid.

For housing, the modular scheme is more detailed, and the same basic module is used for both vertical and horizontal coordination. Preferred dimensions are 240, 300, 360, 480, 600, and 720 cm.

Modular coordination in the Soviet Union is especially effective for industrial buildings in allowing standardization of prefabricated columns, trusses, roof slabs, and wall panels. Spans and column spacings are large enough to permit reasonable flexibility in plant layout. Modular coordination is equally effective in housing, but with the very limited number of standard designs its value is less apparent.

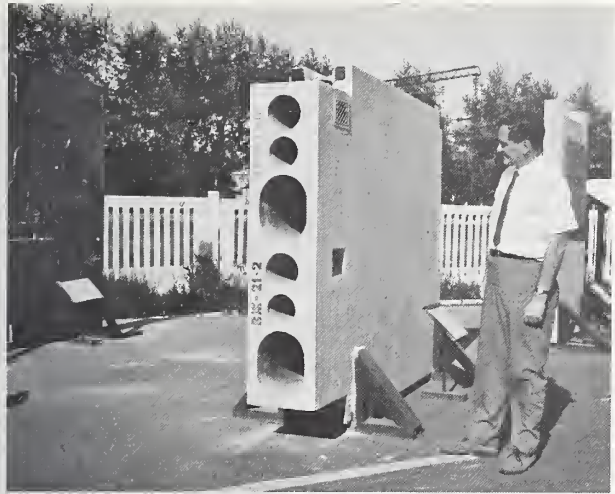
Materials

The Tradition of Brick

Brick is the traditional material in Russia. As one Soviet official put it, "We know brick construction. We know how to use the material. It's not too expensive. The only trouble is that the brick system requires skilled masons who are few in number and a longer building time which we can't have." Another official, rationalizing why they were having such a hard time keeping the panel-built and box-built housing in good maintenance, added this perspective, "Our people simply do not know how to maintain these prefab buildings. If they were of brick, we would have no problems." Nevertheless, brick seems to be on the way out.

Moscow Exhibit: Utility Wall Panel with Piping Cast-in

Although the Soviet standard for plain and reinforced masonry SNip II-B.2-62 has special provisions for vibrated brick panels and brick block assemblies, for all practical purposes only conventional masonry is being used in the USSR. Highly mechanized and automated brick plants have been developed, but experiments in brick panel prefabrication have apparently been discontinued. As one official phrased the decision, "Our brick is not very strong. We dropped the project. Brick must still be laid by hand, even at the factory." Unless there is advancement in brick technology, brick will be obsolete except for remodeling the old portions of the cities. An official of the Moscow office for design and construction said, "85% of the houses are prefabricated; 15% are brick. We are doing our utmost to get away from brick altogether." Brick is dominant as a Russian tradition, but general goals for


Moscow Exhibit: Utility Core Panel with Conduits Cast-in

future construction are massively in favor of precast concrete.

The Move to Precast Concrete

Precast concrete is preferred. The USSR logic is quite simple: Steel is in short supply at best, and requires a highly skilled labor force not currently available. Brick is traditional, and available, but requires more labor than other materials, in a USSR economy already labor poor. Also, for most of the Soviet Union, brick is seasonal because of hard winters. Cast-in-place concrete is equally limited by severe winters, and by the cost of replacement.

Precasting requires less labor while allowing closer quality control, greater speed of construction, year-round component production in the factory, and year-round construction at the site. All this adds up to rubles saved. With the warning that quoted figures are best used only to establish trends, precast construction is 5-20% cheaper than traditional brick building.

Design procedures for concrete appear to be comparable to those used in the US. Concrete mix quality control appears to be excellent. Soviet standards for reinforced concrete, prestressed and non-prestressed, specify that the design be based on the ultimate strengths of the members. Ultimate construction load carrying capacity, however, may be based on crack formation or limiting deformation, depending on the application. The problem of redistribution of stresses in statically indeterminate structures is being actively investigated in the USSR, but the theory of redistribution of moments is not yet sufficiently advanced to warrant being incorporated in the Soviet standards for reinforced concrete. However, a tentative "Instruction for the Design of Statically Indeterminate Reinforced Concrete Construction Taking Into Account Redistribution of Stresses" was published by Gosstroy in 1961.

The Soviet standard for the design of concrete and reinforced concrete structures NiTU 123-55 specifies the following concrete strengths: 50, 75, 100, 150, 200, 300, 400, 500, and 600 kg/cm^2: these strengths are determined with 20 cm cubes tested at 28 days. The corresponding strengths in English units are 710, 1071, 1420, 2130, 2840, 4260, 5680, 7110, and 8530 psi, but these must be reduced 20%; the US 6 x 12 in. cylinders yield lesser unit

Kiev Bathroom Box: Hot Water Pipe Doubles as Towel Rack

strengths than the 20 cm cubes. The various reinforcing steels specified for concrete range in yield strength from 24,200 psi for hot rolled plain bars to 64,000 psi for cold drawn 5.5 mm diameter wire reinforcement.

The Lesser Materials

A Soviet apartment house is mostly precast concrete, there is little else. Concrete block is used, but for the most part only in repair and in a few interior partitions. It is not a widely used material; it cannot compete with precast in total manhours required for either production or construction. Other minor materials, aluminum and plastic, are not available for use on apartment houses. Steel and aluminum sash are used in some public buildings, hotels, and shops, but for apartments all window framing is wood. Although wood is plentiful in the USSR, sash and flooring are almost the only major use of it west of Siberia. Glass, particularly in large sheets, is not of high quality, and appears to be similar to a poor grade of crystal sheet.

In apartment construction of either panel or box systems, the spatial shell is complete when the structure is complete. Since closets are not built-in, there are few if any additional walls. Finish materials are simply applied to the concrete and the apartment is complete. Floors are typically parquet wood or vinyl tile, walls are universally papered, ceilings are usually whitewashed. Window framing and doors are wood, and sills for windows are of rather thin galvanized metal. It is obvious that the creative energies and resources of the USSR building industry have gone first into basic structure, into precasting concrete, not into finishing.

Utilities for Housing

The Absence of Integration

There is no reason why industrialization should not also apply to mechanical and electrical services. It is clear however that in the Soviet Union this is not the case. While considerable effort has gone into the industrialization of structural and spatial frames, mechanical and electrical subsystems exhibit only economy of material, not of labor. Prefabrication and standardization should theoretically lead to a nice integration of utilities with structure. The trend in Russia may be in this direction, but most construction requires extensive job-site installation of electrical and mechanical services. The US delegation did, however, observe several interesting exceptions.

Moscow Exhibit: Precast Column, Deck, and Wall Assembly

In Kiev, one combine produces a finished bathroom assembly complete with floor, walls, doorways, plumbing and rough-in connections—all cast in one piece. Radiant heating piping and electrical wiring are cast in the walls and floors, leaving only mains and risers to be connected at the site.

In Tashkent, another combine pre-places its radiant heating pipes in the precast floor slabs. The same combine uses rubber tubes to create electrical tunnels in wall and floor slabs which takes the place of conduit. The tubes with metal end-inserts are placed in the reinforcing cage prior to pour. After the concrete sets, the rubber tubes are pulled, leaving the conduit tunnels.

Description of Utilities

Single pipe combination waste and vent systems are typical, with an open relief vent at each floor. Waste lines are cast iron with sulfur joints, water piping is steel, and hot water piping is galvanized. Piping is wall bracketed with the exception of some piping cast integrally within precast bathroom modules. In apartment complexes bathrooms are usually on the interior of the building, and have exhaust ducts to the outside. Operable sash is the only other means of apartment ventilation. Heating is generally done with finned tube or cast iron radiators with manual valves.

Electric facilities for apartments are minimal, consisting of one base board receptacle per room and one ceiling drop cord outlet for lighting; the tenant provides the fixture. Aluminum wire with plastic insulation is frequently precast directly into concrete floors and walls, or imbedded with spackle or grout without mechanical protection into grooves cut or cast in the concrete surface. Some plastic conduit is used as well as conduit tunnels left in the concrete as mentioned above. The bulk of the wiring is done at the site.

One of the most interesting aspects of apartment planning in the USSR is the quite common use of central heating plants for both domestic and heating hot water. In Moscow, water is distributed from fourteen central power plants, usually in the same underground conduit delivering domestic water, gas, and electrical service. The hot water is supplied at 195°F for space heating, and

is reduced for domestic use. The power plants generally burn oil, but fuel in Moscow will be switched to natural gas if sufficient amounts can be obtained from the Arctic Circle—Ob River region, and from Bukhara in Uzbekistan. Moscow does not permit coal burning because of air pollution, and hopes to eliminate oil in favor of gas.

Each apartment has a trash chute to the basement made up of reinforced concrete pipe with special loading door sections at each floor. Trash disposal does not seem to be too much of a problem. As one delegate mentioned, "I am inclined to believe the volume of waste collected from an apartment complex is of little consequence." There seems to be little trash or waste in the Soviet society, a circumstance that is directly related to a Soviet scarcity of paper and paper products.

Pieces, Panels, and Boxes

Building Type Standardization

The Soviet precast concrete industry is rigidly standardized by building types. As a measure of efficiency, most combines are highly specialized, building but one closed system for a single building type. This is especially true in housing.

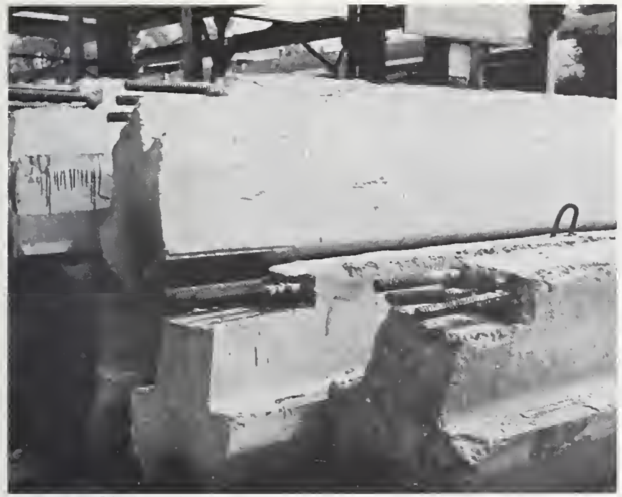
The basic solutions to these various building type problems fall more or less into categories of: pieces—individual column, beam, and planking elements; panels—load bearing wall and floor planes; and boxes—three dimensional room sized modules. Panels and boxes are most adaptable to small-celled buildings requiring little spatial flexibility, i.e. housing. Types requiring more diverse spaces or spans are generally constructed as building frames made up of smaller individual precast elements, or pieces.

Pieces

The Soviets have put together individual precast elements for industrial buildings up to ten stories in height, as well as for long span single story construction. The usual members are story height columns, beams which support either precast or cast-in-place floors, crane girders, and roof and wall closure panels. Prestressed concrete trusses are used for long spans in factories, theaters, and shops.

Kiev Combine No. 1 produces and constructs both longspan and multistory precast concrete buildings. A typical factory is built

Pieces Assembled for Taxi Garage in Kiev



Precast Girders for the Kiev Taxi Garage

A Leningrad Project: Note Inferior Panel Construction

on a standard center line column spacing of 12 meters up to a maximum of 18 meters. Truss spans between column rows are 18, 24, and 36 meters with the emphasis on 24 meters. Concrete roof planks are 3 x 12 meters. Foam insulation and one layer of rolled roofing complete the roof. The usual factory thus constructed is 16,000 ft ^{2} in area. One crane operator and five workers completely erect columns, walls, trusses, and roof.

Combine No. 1 is very special in that it also designs and constructs "unique" buildings requiring non-standard design, but still using precast concrete technology. The bus garage for 550 buses in Kiev is an outstanding example of the Soviet "unique" building. Heading this prize-winning combine is an architect who said that initial plans called for a standard rectangular building, until he intervened. "A building must have a soul," he said. This one does; it is a most imaginative, stimulating structure. It is circular in plan 525 feet in diameter. The suspension roof is supported by 84 precast columns at 20 foot centers on the perimeter which carry a cast-in-place compression ring that anchors 84 cables strung from a central concrete core 55 feet high. Prestressed precast thin shells rest on the cables. Large precast forms were erected over the columns to receive concrete as a pie crust receives filling for the great compression ring anchorage. This tension roof structure was designed and pretested for wind and snow loads with a one-tenth full-size model. The bus garage is truly a unique building.

Panels

The overwhelming effort of the last two decades of housing has been in panel construction—panels as loadbearing walls, and as floor and roof slabs. There is an apparent trend to the newer development of boxes, complete prefabricated room sized modules, but panels still continue as the mainstay of the precast concrete industry.

The Soviets stack panels in eggcrate fashion to 21 stories but plans are ready to go even higher to 30 stories. Structure for panel building is in loadbearing transverse and longtitudinal single story interior wall panels, tied together at each level by floor slab diaphragms. Exterior wall panels are not normally loadbearing. Normal weight concrete is typical, though lightweight concrete is not unusual for precasting. Panels and slabs average 5 tons up

Pin and Socket Detail: Leningrad

to a maximum of 10 tons. Transportation is considered within economic limits if factory to job site is no more than 150 kilometers (93 miles).

How to tie panels together in a deck-of-cards rigid frame is a universal problem; holding the big panels in place with temporary connections is another problem. The Soviets handle both problems with the same methods used in the rest of the world. Welding or bolting of steel inserts and grouting is common. Sometimes a hairpin rod extending the height of one panel and projecting from the top is both lifting hook and pin seat for the panel above. The hairpins mate top to bottom of the next panel, and can be welded or grouted, or both. Combine No. 2 Leningrad has some ingenious solutions, particularly for the problem of connecting the panels until the grouting sets. A steel sprocket link very much like a screen door hook and eye holds the panels in place temporarily until the joints are grouted. After set, the steel serves as corner reinforcement. In this particular case, there is no attempt to hide the joints between panels; an inch or so is deliberately gapped to articulate the connection. A rubber-like waterproofing gasket seals the joint. One Tashkent factory toothes the floor slab for reinforcing and grout interlock with the bearing wall.

No temporary building enclosure is made for winter construction in the Soviet Union, even in the coldest temperatures; a few rooms in the building are set aside for periodically warming the construction workers. To set grout without freezing, typical practice calls for the use of chemicals or electric resistance heaters.

Though not exactly a raging controversy, there is decidedly mixed opinion in the Soviet Union on the relative values of panel and box construction. As mentioned, panel construction is the backbone of the housing industry, but boxes have a decided appeal for the future. Cost of course is the major turning point. Though there are many useful cost indices, minimum on-site labor is a favorite target. Panel construction has been developed to a limiting 55% factory labor, 45% job site labor; box construction holds out the promise of increasing this ratio to 65-35%, or even 70-30%. The savings is in decreasing the number of welded and grouted connections necessary between precast panels—the

Bathroom Boxes Await Finishing: Leningrad

larger the component the fewer the connections and the better the quality of interior finishes if more of the work can be performed in the factory.

Boxes

Box module production is not new, but has been mainly directed to bathroom units of normal concrete, the total units weighing up to 10 tons. The units act as conventional load bearing planes with integral connections at the corners. Some apartment buildings have been built recently, however, with full size precast room modules. Full scale experimentation is now very much in progress. In 1968 one box weighing over 20 metric tons was cast the width of an apartment house, and was shipped all the way to East Germany and back without a crack. The problem though is not so much how to build a big box, but how to move it and put it in place. One Soviet spokesman said that the largest box routinely manufactured in the USSR is 3m x 6m x 2.8m (9.84 ft x 19.68 ft x 9.18 ft), but it is clear that this is but a beginning.

The Soviets state they are considering two maximum dimension targets: the first, a box 3.6m x 11m x 3.3m (11.81 ft x 36.09 ft x 10.83 ft) and the second, a box 5m x 8m x 3.3m (16.41 ft x 26.25 ft x 10.83 ft), both with walls up to 9″ thick. These will weigh up to 25 metric tons (27.5 net tons). The Soviets claim an ability to construct trailers to transport these boxes but answers are inconclusive as to whether they will fit on roads and bridges and under overpasses. Lifting them into place on ever higher buildings is no small problem. Moscow has a code minimum of 9 stories for its new apartments; it will take a major change in equipment to position units for such buildings.

The great disadvantage of the box system is its inflexibility. Rooms can be just so large, and they cannot be changed because the box walls are loadbearing. An experimental box developed in Kiev was designed by an architect to help solve this dilemma. The Kiev unit is not exactly a box with loadbearing walls, but is more like a structural frame cage. The vertical loads are carried at the heavily reinforced corners of the box module; large openings can be made in the walls when there is a need to open the interior space. The inside walls are only 2½ inches thick. In addition to the flexibility for initial planning, large areas of the walls may be

knocked out during renovation, in itself a feature. The experimental house, although relatively small, about four stories, had all its boxes in place in ten days. One of the apartments had a large opening between two boxes, the living room and supposedly the dining room, which gave a spacious appearance never found in the other box system apartments. The box is factory-built without a bottom. Where cantilevers are desired for balconies or bay windows the precast floor slabs are simply made longer. It is a more complicated box and unquestionably more expensive, and the problem of manufacturing the thin walls is not fully solved. Size is still a restriction: 4.7m x 3.1m x 2.7m (15.42 ft x 10.17 ft x 8.86 ft), but a new Kiev box will be larger: 5.8m x 3.4m x 2.7m (19.02 ft x 11.15 ft x 8.86 ft) weighing 13 tons.

The Great Debate

The question of cost is the determining factor for development of box construction, or continued reliance on panel construction. There are ready arguments in the Soviet Union for one or the other. One official said that the panels were much better. He conceded however that "the boxes were of the future." Apparently boxes have a big future. A recent USSR law authorizes 27 factories throughout the USSR to make five story and nine story houses from three dimensional components. Another spokesman, a proponent for boxes, said, "Boxes are better than panels—and cheaper. At present, the cost of labor to build a 3-D house is 2½% less than needed to build a panel house. We have a target to make it 10% cheaper using half the labor." He went on to say that the total cost of the box system could be broken down to 15% labor, 60% materials, and 25% for other items such as transportation and equipment.

In all probability, panel construction in the Soviet Union will continue indefinitely as the primary industry for housing. It is at least equally certain, however, that boxes will receive the full force of Soviet experimentation and development as the method of the future.

The Demise of the Architect

The Problem of Atrophy

Russian officials claim that a shortage of architects in the USSR is reason enough for the necessity of highly standardized design. Perhaps this is so. On a per capita basis the USSR has fewer than one-sixth the number of architects that Bulgaria has and one-tenth

the number England has. In any case it is apparent that architects have not been close to power centers which have directed the industrialization of building in the past two decades. Architects are rarely employed as designers in the factories or combines and when they are their work is largely that of the decorator. All design is furnished by republic or city gosstroy, and is derived from rigidly standardized systems.

An architect in the Soviet Union is fortunate to work on the conception and design development for a "unique" building or new system every other year; his American counterpart will probably be involved in the design of five buildings *each* year. Atrophy of design skills is a very real problem for the Soviet architect. An overriding concern for economic efficiency is the reason for this situation. A combine which manufactures 16 story apartment blocks can ill afford retooling every time a bureaucratic architect decides he can design a better building. True, combines attempt continuous improvement in their products, but equipment and machinery expense precludes major retooling for new or revised models in periods of less than 3½ years. Most officials say to change a series requires 3½ to 5 years; one Soviet made a side remark that "5-10 is more realistic." Change in construction does not hurry in Russia.

Catalog Systems

Systems for Soviet construction are largely closed. There has in the past been little attempt to design systems allowing interchange of precast components or allowing a significant degree of planning and formal flexibility to the architect. This situation may now be changing. The State Committee on Civil Construction and Architecture of USSR Gosstroy has developed a series of catalogs of prefabricated building elements for mandatory use in new design and new factory production. The system provides for interchangeable components and will allow extensive design options. Theoretically these catalogs provide all the benefits of mass production with a diversity of planning options.

Just when the catalog system will apply is another question. One official was very pessimistic; he said that "such a system is still just a dream and far from reality." Others were optimistic and felt that if this system didn't work, then other means would be found to relieve the awesome sameness of the typical neighborhood unit. During the final wrap-up session in the main office of USSR Gosstroy an official summarized the situation. "We readily admit that there are too many buildings of the same type and the districts are looking too much alike. The government is taking action to make the factories more flexible. One target is to create new factories, each of which will be able to manufacture more than one type of house. We are also seeking ways for the various factories to build interchangeable components which will encourage cooperation among the various combines and specialized trusts. We see the need and are taking steps to create conditions which will allow architects, engineers, manufacturers, and builders to provide dwelling blocks which will vary in character, size, and height."

Part Five
Production

The Trend Toward Turnkey Responsibility

Combines and Trusts

The combine brings together in one management the precasting plant and the building trusts responsible for erection and finishing. This "turnkey" organization is preferred to the older division of factory and trust. Leningrad is a good example in giving scale to these operations. Glavleningradstroy, the city gosstroy, has under its authority the following construction industry:

Five combines produce and erect panels and bathroom elements for housing.

One combine produces and erects panels for schools and nurseries.

Twelve building trusts erect brick and cast-in-place concrete buildings.

Eight specialized trusts do site clearing, excavation, foundations, sanitary, electrical, mechanical, special and finishing work.

The numbers of buildings that these large organizations construct are impressive; in 1969 they completed 50,000 apartments, 20 schools, 30 kindergartens and nurseries, 5 movie houses, shopping centers, a hotel and a sports palace.

One combine will generally build most of the precast houses in a given area. It is claimed that each combine knows how much construction is to be authorized for an entire year, and 30 days in advance of its needs the combine tells the authorities how much raw materials will be required. As an operations example, Combine No. 2 manufactures panels for apartment buildings, delivers and erects them and finishes the buildings. Excavation, foundations, electrical and sanitary work are subcontracted to specialized trusts. The combine is divided into two principal departments, one for panel fabrication, the other for erection. A general manager controls both departments. Other administrative support functions within the combine are Administration and Transport, Economics, Engineering and Safety, Planning, and Accounting.

Turnkey Justification

The combine has the blessing of USSR Gosstroy. The following reasons are frequently given for this direction:

A single authority for construction is the direct approach.

Internal communications mean fewer communications—which means faster construction than in shared responsibility.

Mated production and erection are more economical together than apart. To illustrate the point regarding *feedback,* consider the large housing project located on the right bank of the Neva River, District 13, Leningrad, House 39. This unit has a very spacious stair well, but very small kitchens. Because of current pressure for larger kitchens the combine decided to change the model and make the kitchen larger. So the factory will be retooled to produce a modified model for larger kitchens at the expense of smaller stair wells; and the change will require one year and two months. The building will remain the same length and square footage.

In the rush of enthusiasm to the combine approach there are, however, dragging feet. One official came out very strongly against combines. He said, "Let the builders build. A builder is always a builder. Let the manufacturer make things which he loves to do. He should not build." He considered himself a manufacturer and said, "We manufacture exerything except bird's milk, and this includes machines to manufacture machines, not to mention large houses." He argued that when the manufacturer tried to build he would be tempted to put the rejects into the buildings so that the factory would show a greater profit. He emphasized, "We believe in specialization. Our job is to manufacture the elements. Let other specialists build the building. When we deliver an element to the job, it has to be good. If not, it will be rejected by the builder and that is the way it should be.

Despite this man's zeal, however, his views are not shared by most other officials with whom the US delegation visited. Most believe combines solve construction problems more efficiently than do the specialized building trusts, and that the combine is the future for the Soviet building industry.

Precasting Plant Operations

Moscow Concrete Industry

There are 106 precasting plants in the USSR, 28 in the Moscow area alone. These are no mean operations. A typical panel plant may well range to 250,000 yd^3 of product per year or the equivalent of 15,000,000 ft^2 of panels. This is enough to build 5,000,000 square feet of building containing 7,000 average USSR apart-

ments. The Moscow factories listed below produce a yearly volume of 5,100,000 yd^3 of precast concrete for housing; the information is from *Technical Progress in the Industry of Construction Materials of Moscow,* Stroyizdat, Moscow, k-31, USSR, 1967.

Combine No. 1	Fabricates light-weight exterior wall panels, wall blocks for basements, regular brick and light-weight aggregate;
Combine No. 2	Fabricates light-weight concrete exterior panels, precast concrete partition panels, wall panels and electric panels of the attic, balcony slabs, stair flights and landing, elevator slabs;
Factory No. 3	Makes hollow-core precast concrete slabs and hollow blocks;
Plant No. 4	Makes hollow-core precast concrete slabs, ribbed roof slabs and precast concrete partition panels;
Plant No. 5	Makes hollow-core precast concrete slabs, slab supports and lintels;
Plant No. 6	Makes solid slab panels, partition panels, elevator shaft panels, stiffening walls, and precast concrete hollow-core slabs;
Plant No. 7	Makes bathroom modules, ventilation shaft elements, partition panels, heating panels, plenum boxes and girders, beam panels for garbage collectors, elements for dry and wet collectors, elements for pedestrian overcrossing and street panels;
Plant No. 8	Makes hollow-core precast slabs, ribbed slab panels, and supports, floor panels for framed construction, detail elements for buildings of the Series II-49, sunshade slabs, wall panels for entrances, and supports for exterior lighting fixtures;
Combine No. 9	Makes interior bearing wall panels, slab panels, wall panels for lean-to ventilation blocks, roof slabs, slabs for machine rooms, wall blocks for basement, and heating lay-out;
Plant No. 10	Makes exterior light-weight panel for kindergarten buildings, schools, and hospitals;
Plant No. 11	Makes precast hollow-core slabs, foundation blocks, school blocks, girders for frame construction, columns with spherical heads for multi-story buildings, and wall blocks for basements;
Plant No. 12	Makes foundation blocks, road panels, and foundation blocks for basements;
Plant No. 13	Makes columns for housing and public construction, girders for block buildings and multi-story buildings, equipment supports, rafter beams, bracing walls, tie beams, slabs for shafts of wells, precast piles, foundation blocks and mats;
Plant No. 14	Makes stair treads, mosaic work, window sills, parapet blocks for school buildings, parapet stones, flower boxes, floor tile;
Plant No. 15	Makes conduits of large and small diameter, sub-slabs, slabs for covering basements, ventilation shafts, slabs with holes in them, stair supports or consoles, foundation blocks and wall blocks for basements;

Plant No. 16 — Makes ribbed slabs and hollow-core slabs, girders for apartment houses, beams and slabs for major repair of buildings, lintels, wall blocks for basements;

Plant No. 17 — Makes tile, channels, lintels, foundation pads, foundation blocks, border stone, wall blocks for basements;

Plant No. 18 — Makes floor and roof slabs, ribbed and hollow-core, trusses, roof girders and beams, details for refrigerators of the Series II-70, details for new aeration station, columns and girders for frame construction, plain support beams, double-T panels, interior bearing walls for the basement portion of buildings, stiffening diaphragms or shear-walls, and road panels;

Plant No. 19 — Makes lintels, balcony slabs, eye-brow slabs, corner details, panels for television towers and wall blocks for basements;

Plant No. 20 — Makes exterior walls of light-weight concrete and electrical panels;

Plant No. 21 — Makes exterior walls and concrete light-weight blocks;

Plant No. 22 — Makes columns, beams, and girders and posts, tile, road panels, wall blocks for basements and details for a new aeration station;

Plant No. 23 — Makes large and small diameter unsupported conduit (large pipes), collector details of rectangular design, elevator shaft, ribbed slab, details of heating systems and round columns;

Plant No. 24 — Makes ribbed slabs, columns, foundation beams, slabs for industrial buildings, foundation blocks, hollow-core slabs, tile, collector blocks, road panels, wall blocks for basements, and normal-weight brick.

(The Moscow Plant of Reinforced Concrete Pipes or Conduits) Makes long span and short span pipe, tile, beams, columns, telephone wells, collector blocks, slabs for the covering of underground rooms, roofs for the telephone wells, blocks for the heating system, road panels, fence detail, and hollow-core slabs.

(Plant for Wall Material) Makes blocks for interior walls of apartment buildings and regular brick.

(Combine of Construction Material) Produces the interior wall blocks of so-called silicate-concrete and other machine building components.

Production Flow

With thousands of apartment units being built to the same design, the guarantees to a prefabricating plant are substantial. Materials and production scheduling is claimed to be a year in advance, which allows in turn the neat scheduling of labor and equipment at the construction sites. However, there is not enough storage for "surge piles" to ensure continuous construction. In a zeal for perfect materials flow, the combines have trucks, offices, and construction sites linked with radio; theoretically the trailer can be loaded at the plant, trucked to the site, and off-loaded directly into place on the building. One plant shown to the US delegation has an elaborate computerized dispatcher rigged to

green light (ok), yellow light (low inventory) or red light (stoppage) for every item in the chain.

Despite this kind of concern for controlled flow, factory to job-site coordination, there are many idle tower cranes. Even with a standard three shift day the factories cannot keep up with the great number of buildings under construction.

Factory equipment and machinery is a tremendous investment for the Soviet Union. It is heavy, and designed first to increase production with relatively unskilled labor. Vertical battery molds, stationary beds, and conveyor equipment are all heavy and inflexible by Western standards, but are well suited to Soviet requirements; plants are designed for true mass production of highly standardized components. Basic model changes are not frequent. Though it is claimed that a panel plant can accommodate a panel dimension change every three or four hours the change could well take 4 to 18 months for combine, city, republic, and state approval. The plants produce and produce again the same basic models year after year with no interruptions to the production line.

Plants producing precast concrete are highly mechanized large capacity factories. Production techniques range all the way from fixed station operations to the most sophisticated continuous conveyor systems.

Vertical Battery Molds

One plant visited by the US delegation has 30 battery molds, each with about a 12 panel capacity. These are primarily for interior partition panels requiring no special finish or insulation. The molds are made up of leaves which separate the panels, and provide heat for curing. Concrete is supplied to the batteries from overhead hoppers, and internal vibrators are hand operated by men or women standing on top of the mold. Panels are usually room height and finish. Extremely good finish and dimensional accuracy is possible with this kind of operation.

Fixed Casting Beds

The plants producing products for industrial buildings are not as highly mechanized as most panel plants. Column-beam-truss components are generally produced in fixed casting beds. Trusses are made by precasting the diagonal struts of the truss. These are then placed in the forms and cast into the compression and tensile chords of the truss with interlocking reinforcement. The tensile flanges of trusses are pretensioned with a large number of small diameter deformed wires. Prestressing steel has a light copper cladding which is applied during manufacture to prevent corrosion of the steel in transit or storage.

Although new panel plants are generally built as some variant of the conveyor system, some panel plants still operate fixed casting beds. In one plant, concrete is delivered in buggies pulled by small tractors. The buggies are lifted by overhead crane over the panel form and dumped. After finishing operations, an electric radiant heat curing hood is lowered over the new concrete, completely covering the panel.

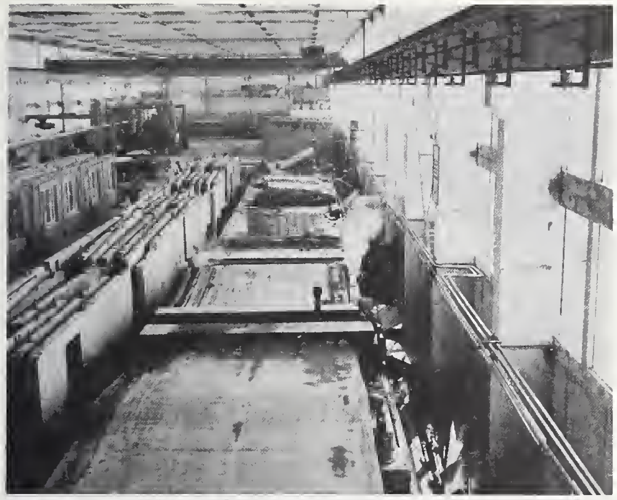
Pallet Casting Trucks

Two variations of this casting system are quite common to Soviet panel factories. In the earlier version a form is prepared on a pallet, the panel is cast and finished, then the pallet is picked up by overhead crane and moved to the curing room. In a more mechanized version heavy steel pallet trucks with wheels are hooked together, and are pulled in a train through various operating stage positions. Each pallet truck receives the framework for a single panel.

Conveyors

Conveyor casting is used extensively in the USSR, and represents at least the immediate future for the precasting industry. Earlier once-through start-stop conveyors have evolved into highly sophisticated two level systems that return the form carriages to a common production line starting point. The heavy steel forms have made it possible to effect good edge control and curving. This type of production line produces loadbearing as well as non-loadbearing panels with good exterior finish and complete fabrication. Prestressed components are produced effectively and economically. The excerpts below from *Technical Progress in the Industry of Construction Materials in Moscow* give full descriptions of the two level conveyors used in Moscow:

> What do these two-level conveyor lines consist of? First, let's look at one of the modifications to such a line which was devised by the Institute of Moscow Construction. These kinds of lines are


Moscow: Two-Level Conveyors for Panels

now in operation in Plant No. 6 and Plant No. 9.

The two-level line consists of a horizontal conveyor of the cart type. The elevator lifts the formwagon from the lower level to the upper level. The pusher moves it to the first position where a bridge crane pulls the components out of the form (stripping the product). The formwagon is then pushed to the position for cleaning and oiling. As the following positions are passed, the reinforcing is put in place and the cast-in components are installed, the electrical conduits are installed as well as the inside piping which are afterwards cast into the panels. The completed form is then pushed into position for concreting. The concrete is poured and compacted with the aid of vibration and finished with mechanical screeds and rollers.

The completed form is moved to the next position where the block-outs are removed, and then to a compartmented chamber for curing by high pressure steam. After the high temperature curing the component is directed to the area of cooling. Then the cycle is repeated. The form-wagons are put into motion by pushers located at the elevator end of the line. The yearly production is 400,000 square meters of panels (4,400,000 sq. ft./yr.).

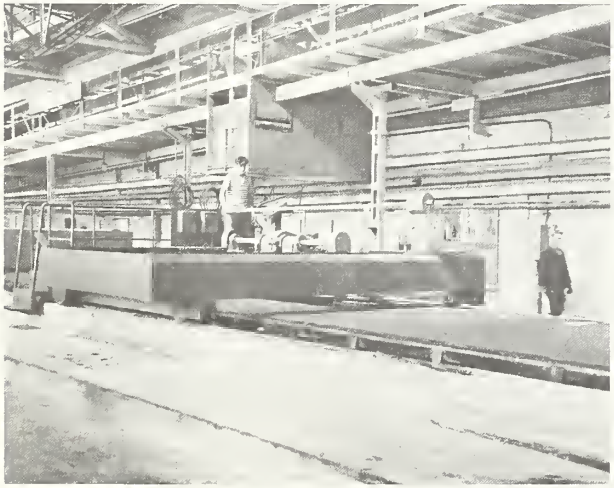
Interior bearing walls are fabricated in 29 different dimensions with concrete of Grade 200. They have a thickness of 140 millimeters (5.5″) and a length from 1,720 to 6,060 millimeters (5.7′-20′) and a height of 2,520 millimeters (8.3′). There are also fifteen different geometry panels which are also made from 200 Grade concrete of thickness 140 millimeters (5.5″), length 1,700 to 6,060 millimeters (5.6′-20′), width 2,560 to 3,280 millimeters (8.5′ to 10.8′) with cast-in electric conduits.

A two-level conveyor line of a different size is also installed in Combine No. 4. It consists of a

Moscow Conveyor, End Station: Form Stripping and Removal

Moscow: Concrete Emerging from Curing Oven

Moscow Concrete Conveyor: Finishing Operations



Moscow Concrete Conveyor: Vibrating and Screeding

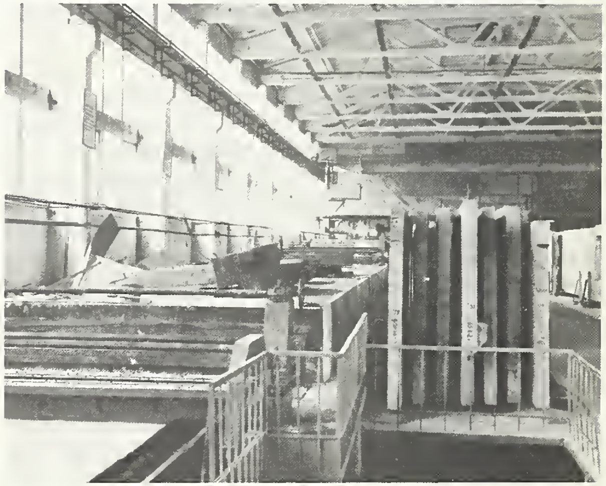
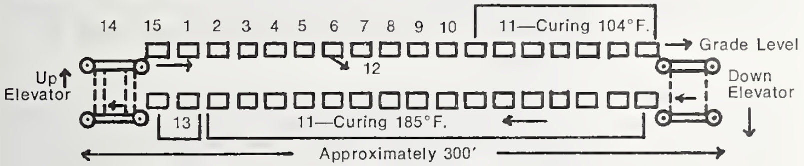


ILLUSTRATION 29. SCHEMATIC OF TYPICAL USSR CONVEYERIZED CONCRETE PANEL FABRICATING LINE



1. Clean and oil form
2. Place prefabricated rebar "cages"
3. Place conduits, pipe, wire
4. Place blockouts (for windows, doors, receptacles)
5. Pour concrete from overhead hopper or belt, and vibrate
6. Screed
7. Trim waste
8. } Preheat chamber
9. }
10. Remove blockouts
11. Curing—104—185°F.
12. Waste reclaim conveyer
13. Cooling chamber
14. Tilting bed for reducing panel strain during lifting from form
15. Lift panel from form by overhead crane

chain type horizontal conveyor with a continuous (uninterrupted) motion of approximately the speed of a walking man with a driving and take-up pulley; it also has the vertical finishing conveyor. The maximum dimensions of the components that can be produced in this conveyor are 2.54 m wide, 4.95 m long, and 140 mm high (8.3 ft x 16.2 ft x 4.6 ft).

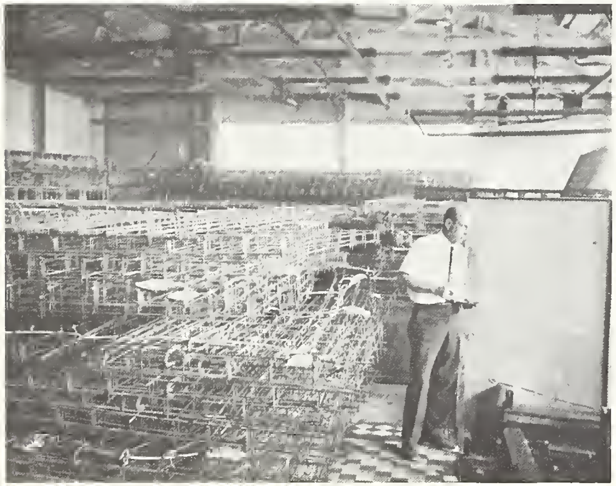
In the same way a new technique was devised for the production of the exterior peripheral panels for buildings of the Series II-49 on these new two-level conveyor lines which were installed at Combine No. 1. These lines produce light-weight wall panels in double or single module dimension for exterior panels to be used in housing construction of Series II-49. The maximum dimensions of the panel will be 6,740 by 2,680 by 340 millimeters (22.2′ x 8.9′ x 13.3″).

Two double level conveyor lines and flow assembly lines which are now in production at this combine could provide all the necessary panel work for an overall area of 500,000 square meters (5,500,000 sq. ft.) per year.

The conveyor lines are located in the side spans of the factory building. In the central portion, the cleaning of the ceramic facing is done as well as the finishing of non-horizontal surfaces. For transportation operations, a 10-ton bridge crane is employed.

The conveyor line consists of two levels; on the upper level are distributed stations and mechanisms for the production and finishing of the exterior wall panels; on the lower level is a compartmented chamber for curing, equipped with electrical curing and heating systems.


Kiev: Reinforcing Cage Fabrication

Kiev: Reinforcing Cages


The panels are produced in formwagons; the motion is a pulsating type with 24 minute cycles. For the moving of the formwagons horizontally, there are little car pushers; and for vertical transfer, there are elevators located at each end of the conveyor.

The light-weight concrete and the mixes for the lower and upper layer are supplied through a scaffold with two coupled concrete containers. From the concrete containers the mixtures and the light-weight mix are admitted into mix distributing machines and light-weight distributing machines with vibrators.

The technological process for the fabrication of components is described below.

The formwagons are taken out of the slot of curing chambers with the help of the elevators to the stripping station. The panel is stripped with the help of a crane and put onto a transition cart which takes it into the central bay for the cleaning of the ceramic facing and then to a stand for miscellaneous work. From the stand the product goes to a shelf for testing purposes and then into the storage area.

After stripping, the formwagon moves to the station for cleaning and oiling, then for the placing and consolidation of light-weight concrete, two layers of other mix, and screeding. The last process operation on the upper level is the smoothing of the cast product which is done by a special machine for this purpose.

Following this operation the elevator takes the product down to the compartmented curing chamber. The thermal curing is done at 110° centigrade for 8½ hours. The moisture content of the panel,

as it comes out of the curing chamber, is approximately 8-12%.

A central control regulates the function of all the separate mechanisms as well as the rate of production.

Combine No. 2 for project CKTB has in operation a conveyor automated line for the purpose of producing light-weight double module exterior panels for nine-story buildings for the new Series I-515-9. Different from all the others, this procedure employs a quick stripping after casting and curing through the use of infrared rays.

The compartmented chamber consists of a reinforced concrete tunnel built above the ground. Inside, above and along the sides of the chamber are mounted 954 electric heaters of the tube-type emitting infra-red rays. These tubes contain a non-chromated spiral. The space between the tube wall and the spiral is filled with compacted magnesium oxide.

The line works as follows: the intermediate carts supply the conveyor with clean and oiled formwagons. In the formwagons are placed carpets of ceramic facings on top of which is placed a 20 millimeter (0.8 in.) thickness of concrete mix before placing the reinforcing steel.

The formwagon together with the ceramic facing and the reinforcing steel is then put on a vibrating table. Here, the concrete is placed and compacted. The placing machine finishes the top surface. Then the edge forms are dropped off and the remainder is moved into the curing chamber. The component is then heated for 1½ hours at a temperature of 60° centigrade and is then put in position for the finishing. Then it is put into another curing chamber for 5 hours at temperatures ranging from 90-95° centigrade.

The product and the form are then moved onto scales. At the next station, the product is stripped and the formwagon is sent on for re-cycling. The stripped product is handled by a bridge crane and brought to position for finishing the window and door frames. It is then taken to the storage area.

Curing and Time Cycles

Curing is largely accomplished with steam at atmospheric pressure; some radiant electrical heating is used, but is not primary. In the steam curing process there are four approaches:

Steam tunnels beneath fixed casting beds.

Steam chambers for conveyor systems.

Vertical steam chambers with panels moved vertically to control rate of rise of concrete temperature; chamber temperature increases with approximate uniformity from bottom to top.

Steam channeled into hollow forms for intricate casting—for truss production and for vertical battery molds.

Steam and electric curing time in tunnels or vertical ovens ranges from 2 to 8½ hours, depending on panel thickness, with 6-7 hours for regular panels. With electrical radiant heating under a hood, the curing cycle is reduced to 2½ to 3 hours for regular panels, thus permitting two cycles per shift.

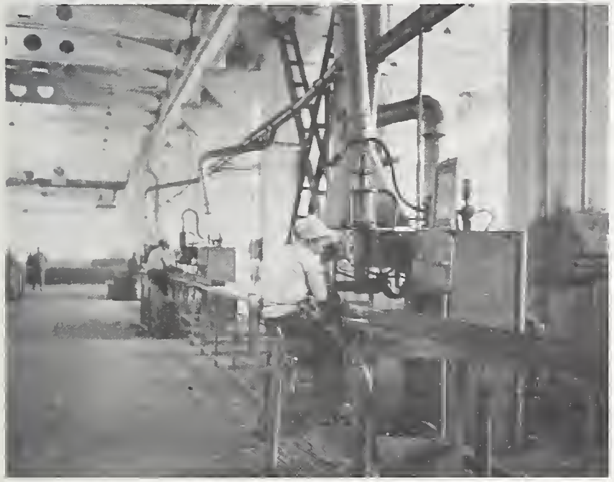
Moscow Combine No. 1

Moscow Combine No. 1 produces lightweight curtainwall panels on conveyorized production lines. The plant has an automatic lightweight concrete batch plant producing concrete of 60 to 66 lb/ft^3, from which panels 12 to 13 inches thick are produced. The lightweight aggregate is made of a low-swelling clay. Most of the exterior panels have a ceramic tile facing with tile 2 inches square by ¼ inch thick, or a decorative facing of glass mosaic. The carpets of ceramic facings are placed face down in the form, followed by approximately one inch of concrete mix before placing the reinforcing steel mesh. The form then moves to a vibrating table where the concrete is poured and compacted. The rest of the process is essentially the same as for regular concrete panels. A recent innovation for the purpose of producing lightweight double module exterior panels is the practice of "quick stripping" after casting and curing, through the use of infrared rays which accelerates the curing process and allows stripping the panel from the form within 6½ hours (1½ hours at 140°F and 5 hours at 203°F). The compartmented chamber consists of a concrete tunnel built above ground. Electric heaters of the tube type emitting infrared rays are mounted above and along the sides of the chamber. These particular chambers take the place of the long curing chambers in illustration 29 which require 8½ hours for curing.

Moscow Combine No. 9

Moscow Combine No. 9, built in 1965, has two production lines for panels, each 320 feet long. There are 24 panels in varying stages of completion on each line at any one time. The production line is a continuously operating conveyer with 12 panels at one elevation and 12 directly below. Each panel is in a different stage of either pouring, finishing or curing. Each line manufactures 47,000 cubic yards of panels per year on 15 shifts per week. The cement is "hi-early" cement; during the curing process, the panel stays one hour at 104°F and then five hours at 185°F—the total curing cycle is six hours. The reinforcement cages are produced by continuous-feed reels, hand controlled welders and automatic cut-off machines. Panel sizes range up to 20 feet long, 10 feet wide and 6 inches thick, although some special panels are made up to 20 inches thick. In addition to floor slabs, exterior panels with ceramic finish, and light cellular 3 to 4 inches thick interior wall panels can be made on these conveyor lines. The lines are located along the


Kiev: Automatic Welder for Reinforcing Mesh

Reinforcing Cage Welding: Kiev


side bays of the shop building. The central bays contain vertical molds, areas for fabrication of reinforcement cages and areas for cleaning ceramic facings and the finishing of other surfaces. The surfaces produced on both the conveyor lines and in the vertical molds are suitable for whitewashing or painting, or for direct application of lineoleum or floor tile.

The plant employs 1,040 people, including those who operate the nursery for the children of the workers, to produce approximately 94,000 cubic yards per year of concrete panels, and 105,000 cubic yards per year of gypsum concrete panels 3 inches thick. Of these people, 840 are on production line, and almost half of these are women. The workers on the production line earn 150 to 170 rubles ($165 to 187) per month with the higher figure including the "above" quota" bonus which is usually made. This income is significantly higher than the USSR urban average of $120, and is given as a reason for construction workers taking factory jobs. In addition, workers get free nursery service for their children, free hospitalization and other amenities such as subsidized vacations at the Black Sea resorts owned by the plant. Combine No. 9 has a rather extensive product line. In addition to concrete panels, the plant mills wood components from logs to finished parquet flooring and furniture. The combine mills sash for the windows of its own panels, and for the panels of other plants, glazes and paints them, and builds built-in furniture for its own housing projects as well as furniture for schools and hospitals built by others.

Moscow Experimental Panel Factory

This plant makes panels for "advanced design" experimental apartment buildings. There are two experimental conveyor lines, each 300 feet long, 14 feet wide, with movable steel molds fastened to the conveyor belt. The conveyor moves 100 feet per hour, including short stops for certain operations. Concrete is dumped onto the belt and vibrated, screeded by hand, and finished by power rollers, all in 15 minutes. The reinforcing steel for these panels is prefabricated into cages and placed by crane onto the conveyor. There is no limit to the length of a panel other than transportation to the construction site; the longest to date has been 46 feet. The panels can be anywhere from 0.8 inch to 14 inches thick. The total time to manufacture a concrete panel is 2¼ hours on the conveyor, including curing. Steam curing at a


Leningrad: Finished Exterior Panels Await Transport

maximum of 185°F requires 2 hours of the 2¼ hours total time, and takes the concrete to 60% of ultimate strength. The steam curing takes place in a vertical oven which stacks the panels for the required time. Molds are set so that a top layer of lightweight concrete can be added to the regular concrete underneath.

Kiev Trust No. 1

Kiev Trust No. 1 (Brovary) is unique in that its product line includes trusses, panels, *and* boxes. The trusses are poured in place in horizontal steel-jacketed molds with a curing time of 15 hours at a maximum temperature of 185°F. 82% of the components produced are prestressed. One small tensioning machine has a 60 ton capacity and another has a 500 ton capacity with the ability to pull all strands at once. Loadbearing wall panels are poured in horizontal molds and have a polystyrene wall insert for insulation. Concrete is delivered from the mix area to the panel molds by rubber belt while the concrete is being vibrated, electromagnets which keep the forms from jumping. A large panel is poured every 30 minutes, for the equivalent of 14 panels per shift. Most of the curing for panels is accomplished by jacket heating of the molds, but ovens are the preferred method. A small amount of the panel production can be accommodated in a few batch-type ovens located in the outdoor storage yard. The goal of this plant is 180,000 cubic yards of concrete panels per year; at present the actual production is 120,000 cubic yards. In addition to this panel product, boxes 10 by 16 by 10 to 12 feet high are manufactured for five story housing.

Leningrad Combine No. 2

The Leningrad House Building Combine No. 2 manufactures bathroom boxes and reinforced concrete panels. The boxes are three or four walled assemblies plus ceiling or floor, cast as a unit and transported to the site. Separate spaces are formed for the toilet, the bath, and the heater. The boxes are poured in vertical molds with the mold panels opening out; the interior form is tapered. Steam passes through the inside form for curing. Before the box leaves the factory, the toilet, washbasin and bathtub are either totally or partially installed by a separate sanitary trust charged with the responsibility for piping and final site installation. Boxes are vogue. There are only four operating box plants in the Moscow area now, but current plans call for constructing 28 factories for concrete boxes in the Moscow region alone. These boxes will be

for housing and stores, as well as for bathrooms. Each new plant will have a capacity to produce boxes for 2,000,000 square feet gross building area per year, or 3,000 USSR apartments.

The panel fabrication plant of Combine No. 2 occupies 43 acres. The concrete moves by belt from the batch plant to the casting plant and is poured into the panel molds. The panels use a haydite type of concrete. A typical panel is 8.5 x 21 feet x 12 inches thick. On one of the production lines, the panels take five hours for curing out of a total cycle of eight hours. On another production line, the total time of manufacturing a panel is 12 hours including 8½ hours for steam curing. Panel curing starts at 77 to 86°F, with a rise of 18°F every 20 minutes until it reaches th upper curing temperature of 194 to 203°F. Following this, the temperature is gradually reduced until the panel leaves the curing chamber at 68°F. One panel is finished every 22 minutes. The maximum storage area for finished panels is 3,000 units with an average storage time of one week.

Tashkent Combine DSK-1

DSK-1 produces panels, assembles them at the site, and erects and finishes the building, including the roofing. Electrical, sanitary and foundation work is subcontracted to the various specialty trusts. For a typical 48 unit apartment house, the combine's materials and labor will represent 76% of the total cost of the building (the combine does not make its own windows). The other 24% consists primarily of foundations, and electrical and mechanical work by subcontractors.

Factory No. 1 of DSK-1, built in 1959, is clean, neat and not cramped. It produces heavy panels for four and five story houses. Its capacity is 6,000,000 square feet of total building area per year. Factory No. 1 uses both vertical and horizontal molds. The vertical molds are cheaper, but less flexible. Panels can be poured and cured 6, 8, or 10 to a battery in the vertical mold. With the horizontal panels, the windows, which are purchased in Tashkent, are cast in place. Both a batched and a mechanized horizontal pour line are used, the latter still under test. On the mechanized line, one panel is planned every 15 minutes. When the experimental mechanized line is debugged, predicted capacity is 5,400,000 square feet total building area per year based upon a steam cure time of 4 to 6 hours. Since 1960, Factory No. 1 has built panels for 1,500,000 square meters of net living space, or 50,000 apartments on the basis of 30 square meters of net living space per apartment.

Factory No. 2 of DSK-1 produces panels for 4,000,000 square feet total building area per year, with half the panels for four story buildings and half for nine story buildings. All casting is in 90 horizontal molds, with concrete transported to the pouring hoppers by cart, an admittedly inefficient process. Heating of the molds for curing is by electrical resistance coils attached to a cover placed over the panel. Curing time is 2½ to 3 hours, during which the temperature is increased 72°F per hour up to the maximum temperature of 185 to 194°F. The maximum panel sizes are 12 x 23 feet x 5.5 inches thick for floors; 12 x 23 feet x 10 inches thick for the exterior walls; and 12 x 23 feet x 19 inches thick for the interior load bearing walls. No conduit is used for the wiring inside the panel, but the hole is made by pulling out a plastic pipe insert before the concrete sets.

The total number of people at both factories is 1,700 including those operating the boiler plant, plus another 2,700 people at the various construction sites. Women constitute 37% of the erection and finishing work force. The combine claims the ability to finish 162 apartments of an average 30.2 square meters net living space each in 260 working days, in five day weeks.

Kiev Combine No. 3

The labor statistics for the 9 story panel apartment houses produced and erected by Combine No. 3 are useful and reasonably complete. For this reason Table 3 is included in this section.

TABLE 3. KIEV NINE STORY APARTMENT HOUSE

APARTMENTS	53	
NET LIVING SPACE (LIVING AND BEDROOMS)	1667	m^2
NET LIVING SPACE, AVE. PER APT.	31.5	m^2
USEFUL LIVING SPACE (LIVING AND BEDROOMS, ENTRY HALL, KITCHEN, AND BATH)	2389	m^2
USEFUL LIVING SPACE, AVE. PER APT.	45.0	m^2
RATIO USEFUL/NET LIVING SPACE	1.43	
RATIO USEFUL/BUILDING GROSS AREA	Appx. 0.80	

Panel plant averages 144 m^3 finished panels/man-yr. (includes total plant personnel)

Panel plant averages 97.5% yield concrete shipped/made

Panel plant largest panel 6.5 x 6.5 meters
interior panel 3.2 x 6.5 meters

Erection Crane 0.03 man-day/m^2 useful living space (9 stories)
0.02 man-day/m^2 useful living space (5 stories)
1 operator/crane gets 5 rubles/day

Rental (including operator) 15 rubles/day—1st shift
10 rubles/day—2nd shift
0 rubles/day—3rd shift

Transport 4 kopeks/M.T.—km travel M.T.=metric ton
2 kopeks/M.T.—km load and unloading
6 kopeks/M.T.—km total
1 tractor handles 3 trailers
Truck rental 18-20 rubles/day including operator who gets 6 rubles/day

Combine No. 3 will build 4,000 apartments in 1969. 2,200 workers produce 70 m^2 net living space per man-year; the labor distribution is approximately 50% at plant and 50% at site. These numbers exclude the labor from the Trusts which do the below-grade, plumbing, electrical and certain other specialty trades.

Summary of Total Labor Consumption—Combines and Trusts

Panel factory and transport labor	1.7 man-days/m^2 net living space
Site labor	1.8 man-days/m^2 net living space
Total labor	3.5 man-days/m^2 net living space

Details of Labor Consumption		Man-days/m^2 Net Living Space	
Panel fabrication at factory		1.500	
Transport		0.200	
Subtotal Factory & Transport		1.700	Say 1.7
Below grade	0.12-0.15	0.13	
Erection		0.40	
Plumbing		0.20	
Elec./commun.		0.10	
Crane operation		0.05	
Elevator installation		0.005	
Finishing		0.90	
Miscellaneous		0.004	
Clerk of works		0.028	
Superintendent's staff		0.008	
Subtotal Site		1.825	Say 1.8
Total Labor			3.5

Based on an extension of some of the above numbers (i.e. for elevator installation, crane operation and superintendent's staff) to man-days for the job, it is evident that the numbers are too low and thus, the totals are low. The total of 1.825 site labor man-days per m^2 of net living space should be compared with the published figures on Tables 4 and 5.

Cost of materials and labor (excl. district communication lines and landscaping) 120 rubles/m^2 net living space.

SOURCE: Glavkievgosstroy and House Building Combine No. 3, 1 September 1969

Part Six
Construction

The Promise of Efficiency

Leningrad: Nine-story House Nearing Completion

Rapid Construction

All of the republics are concentrating on rapid construction methods; time in the USSR is a competitive commodity. The Ukrainian SSR has reported some of its project experiences of this kind for 1968-69 in *Rapid Construction of Apartment Houses in the Ukrainian SSR,* published by the Scientific-Research Institute of the Construction Industry, Kiev, 1969. This report is in two sections, the first describing the construction of Bereznyaki No. 18, a large panel apartment house in Kiev, and the second comparing four apartment projects in Donetsk oblast. All of these projects are experimental, but only in the methods and organization for erection and finishing; each is a standard USSR apartment design. The Kiev apartment house is nine stories, the Donetsk oblast houses are five stories. As a general overview of the record, the above ground part of the nine story 144 apartment house was completed in 45 working days or 60 calendar days, four times faster than the USSR standard and twice as fast as an earlier record by the same builder for this apartment type. Erection of the floor structures was done in 18 working days, erection of the roof in 4 days, and finishing work was completed in 23 days. For the above ground part of the five story buildings, the one with 60 units took 64 working days, one with 58 units 54 days, one with 45 units 50 days, and the final one with 120 units 45 working days.

The Nine-Story Apartment House

The materials for the Kiev house are typical. The outer walls are 35 and 40 cm thick claydite concrete produced in 20 standard sizes—the claydite is a light weight expanded clay that improves thermal insulation properties of the concrete. The outer surfaces are faced with ceramic tile. Inner loadbearing walls are hollow reinforced concrete panels, produced in six standard sizes. The floors are cross ribbed reinforced concrete panels which come in 6 standard room sizes. Partitions are room sized rolled gypsum-concrete panels. Roof decks are finished with three-layered roll roofing; roof drains are internal. Apartment floor slabs are covered with parquet boards in living and bed rooms, vinyl in kitchen and entrance halls, and ceramic tile in bathrooms.

The following excerpts from the *Rapid Construction* report concerning Bereznyaki No. 18 are valuable as an insight to typical con-

TABLE 4. KIEV APARTMENT HOUSE BEREZNYAKI NO. 18

APARTMENTS	144	
NET LIVING SPACE (LIVING & BEDROOMS)	5,080	m^2
NET LIVING SPACE, AVE. PER APT.	35.3	m^2
USEFUL LIVING SPACE (LIVING & BEDROOMS, ENTRY HALL, KITCHEN, & BATH)	7,222	m^2
USEFUL LIVING SPACE, AVE. PER APT.	50.3	m^2
RATIO USEFUL/NET LIVING SPACE	1.42	
RATIO USEFUL/BUILDING GROSS AREA	Approx. .80	
SITE AREA (FLOOR PROFILE)	1,052	m^2
VOLUME ABOVE GRADE	26,182	m^3
VOLUME BELOW GRADE	255	m^3
TOTAL BUILDING VOLUME	26,437	m^3

Apartments	No.	%	Probable Net Space Unit	Probable Net Space Total	Probable Useful Space Unit	Probable Useful Space Total
One-room	18	12.5	16 m^2	290 m^2	32 m^2	580 m^2
Two-room	36	25.0	27	970	41	1,480
Three-room	72	50.0	41	2,940	56	4,032
Four-room	18	12.5	49	880	63	1,130
Total	144	100.0	35.3	5,080 m^2	50.3 m^2	7,222 m^2

Number of elevators 4; capacity/elevator 350 kg
Concrete below grade 356 m^3 reinforced concrete plus 148 m^3 plain concrete
Concrete above grade 1415 m^3 " " " 2203 m^3 " "*
*Tons steel** outside of reinforcing in concrete 37.8 metric tons 7.5 kg/m^2 net living space 5.2 kg/m^2 useful living space*

WALLS PAPERED	27,535 m^2
WALLS PAINTED	5,140 m^2
CEILINGS WHITEWASHED	7,320 m^2
ROOFING	1,299 m^2
GYPSUM PARTITIONS	6,971 m^2
WINDOWS	776 m^2
DOORS	2,238 m^2
RADIATORS	832 m^2

WAGES—erection crew	7-8 rubles/day
painters	6.5-7.5 rubles/day
floor men	7-8 rubles/day

Above ground labor 2.09 man-days/m^2 net living space

To this must be added below-grade labor, which according to Table 3 and other information would average 0.14 man-day/m^2 net living space. An idea of the improvement reported by the figure of 2.09 man-days/m^2 is indicated by comparison with another reported figure of 2.73 experienced by the same Combine for the same types of buildings constructed during 1968.

SOURCE: Rapid Construction of Apartment Houses in The Ukrainian SSR, *1969, and Glavkievgosstroy 1-3 September 1969*

** Exterior wall panels are considered plain concrete which is lightweight and lightly reinforced.*
*** Rails, balconies, garbage chutes, dowels, sphices, etc.*
**** An idea of the improvement is in comparison with a reported 2.73 by the same Combine for the same building type in 1968.*

struction technique in the Soviet Union. Remember that this is a standard apartment house; only the construction time is changed, with multiple shifts and close priority and coordination of materials delivery to the job site:

> The building was divided, within each floor, into four crane-grab sections for the purpose of rapid erection. The erection was done in two parallel production lines by two half-crews, each of which worked on two crane-grab sections (half of the building) and used one tower crane. To eliminate the transportation of identical parts and structures for each production line during the same day, one half-crew always started working on a floor a day later than the other one.
>
> Erection of each floor took two days, i.e. one day, three shifts each, per one crane-grab section. Other structures of the building were erected in 18 working days, and roof and its covering was completed in four days. Total erection time of the above-ground part was 22 days as compared with an estimated time of 23 days.
>
> The following technique of work progress at each crane-grab section was adopted: first and second shifts of each erection day installed the panels of outer and inner walls at two adjacent crane-grab sections, welded anchoring parts in place and filled the joints of inner walls. Simultaneous erection of wall panels at two crane-grab sections was adopted to increase the work frontage and avoid the possibility of erectors standing idle in case of untimely delivery of certain panels. During the third shift of the first erection day and during three shifts of the second day the following operations were performed: installation of partition panels and concrete floors in bathrooms, laying the base for floors, erection of floor panels, stairways, balconies and trash-ducts, welding of an-

choring parts, sealing of wall and floor joints and caulking of partitions.

While an upper floor was being erected, the following work was being done at a floor below (one floor between): plumbing and electrical wiring, carpenter's work, plastering, installation of door frames and finishing of woodwork.

Plumbing and electrical wiring work was done during the first shift starting on the fourth working day, carpenter's work starting on the sixth day, plastering and laying of floors in bathrooms on the eighth day.

Finishing work was done after the erection was completed and after the roof was finished.

For finishing work, the building was divided into sections in the same manner as for erection. The work was done simultaneously in all four sections of a floor and progressed from the ninth floor down. Finishing work was completed in 21 days, working one shift a day. The total construction time of the above-ground part of the building was 45 working days or 60 calendar days.

The site for the building constructed by this rapid method was provided with approach roads, parking lots for semitrailers (panel-carriers), areas for storing of structures and materials, crane tracks, two tower cranes (erected and tested). temoprary facilities for everyday convenience of workers, offices of foremen and work superintendents, and fences around danger zones and the construction site.

Temporary roads, 3.5 m. wide, were made of prefabricated reinforced concrete slabs, designed to carry heavy panel-carriers with a total weight of up to 25 tons. Parking lots for transportation vehicles were located in the vicinity of every crane and provided enough space for simultaneous parking of four semitrailers or trucks.

The building was erected with the aid of two S-419 tower cranes of 20 m. boom-out and 3-5 ton lifting capacity. Each crane serviced two crane-grab sections or half of the building. To ensure safe, simultaneous operation of both cranes, their action zones were separated by movable rail stops, set at a distance of 31.4 m. from each other which made it impossible for the booms of two cranes to come closer than 6 m. to one another. The following order of crane work was observed during erection of the structures: crane No. 1 works at the first section (crane-grab), at the same time crane No. 2 works at the third section (crane-grab); crane No. 1 works at the second section (crane-grab) while crane No. 2 works at the fourth section.

Erection of outer and inner walls was done by lifting the panels directly from the panel-carriers.

Two truck tractors Mark MAZ-504 were used to transport structural items to the construction site. Each tractor pulled three semitrailers Mark NAMI-790 and one semitrailer Mark MAZ-5242. By having each tractor pull three semitrailers, it was possible to use a shuttle method in the transportation of structural items.

The number and capacity of the storage areas was calculated to hold a reserve of structures and materials for two floors of the building. An area was also provided for assembling the items of elevator shafts into large subassemblies. Two areas were provided with racks for storage of reserve outer and inner wall panels. In order that such number of storage areas could be placed in the zone of each tower crane, the crane tracks had

to be extended 21 m. beyond each end of the building.

For sanitary and everyday needs the following temporary structures were built: two accommodation barracks for erectors, two for plumbers, one for electricians, seven for finishing workers, three for offices of foremen and work superintendents, a shower-bath and a toilet.

Electricity, water, steam and gas were provided from permanent city lines. Mortar and concrete were supplied by a central mortar-concrete yard.

To prevent loss of time due to power failure in city power lines, the construction site was provided with a mobile electric power station. In addition to ready-mixed mortar brought to the site, some mortar was prepared at the site in a small mortar mixer. Crane parts which most frequently break down were also kept in stock.

Very thorough preparations, which would ensure a successful achievement of rapid construction, were made before erection of the building was started. A plan of work progress for the rapid construction of the building was worked out. An order was issued to the House-Building Trust in which tasks of all the sections participating in the project were defined.

At the job site, all the work on the underground part of the building and engineering structures on the site was completed by the general contractor and accepted. Center lines of the building were plotted by surveyors and screeds for wall panels were provided.

The job site was prepared in accordance with the master plan, cranes were erected and tested and all necessary equipment and tools were brought to the site. Cross-ribbed floor panels, partition panels and floor material, stair stringers and platforms, anchoring parts, reinforcing rods, etc., were stocked in the amount required for two floors of the building. The job site was decorated with posters, slogans and other means of visual propaganda.

Particular attention was given to the organization of efficient and timely supply of products and materials to the site and their delivery in full conformity with transportation-erection charts and supply records. Control over the delivery of products and materials was given to the chief dispatcher of the Trust.

To ensure reliable communications with the control room of the residential area of the Bereznyaki complex, two radio stations of the ARS and "Altoy" type were installed. The dispatcher of the complex had a two-way radio communication with the central control room of the Trust. This made it possible to record all troubles and to take proper measures for their prevention and elimination, and also to control the departure and arrival of all transportation means.

The crews were made up and they were given instructions regarding the work techniques required in the rapid construction. Work-progress schedules, showing the amount of work required for each operation and their completion dates, were brought to every crew regularly.

The erection crew consisted of:

Foreman VI class	1 man
Erectors IV class	6
Erectors III class	16
Riggers III class	6

TABLE 5. BEREZNYAKI NO. 18 COST ACCOUNTING

CHARACTERISTIC	NO. 18	OTHER HOUSES SAME SERIES
Construction Time		
Total Above Grade—Calendar Days	60	140
Above Grade Erection—Working Days	22	75
Site Labor—Mandays/m² Net Living Space		
Subcontractors Labor	0.48	0.55
Total Combine Labor	1.22	1.69
Above Grade Erectors Labor	0.39	0.49
Total Labor	1.70	2.24
Ave. Fulfillment of Production Quotas—%	180-195	150-155
Cost/m² Net Living Space—Rubles	101.42	104.92
Savings Actual vs. Estimated Cost—%	8.0	4.5
Ave. Daily Tower Crane Output m² Net Living Space	74.85	36.32
Yearly Output of Tower Crane m² Net Living Space	27320	13257

SOURCE: Rapid Construction of Apartment Houses in the Ukrainian SSR, *1969*

Mason-concrete workers IV class	2
Mason-concrete workers III class	4
Metal workers V class	2
Arc welders V class	4
Facade workers V class	2
Facade workers IV class	4
Carpenters IV class	2
Tower crane operators IV class	6
	55 men

Work integrated with the erection was done by five other crews made up of 18 carpenters, 8 tile-layers, 16 plasterers, 8 plumbers, and 4 electricians. Finishing work was done by four crews of painters and two crews of parquet-layers.

The Donetsk Five-Story Apartment House

Again, these apartments, like the nine story Kiev apartment, are typical Soviet Standard apartment series. Three are all panel; Donetskzhilstroy No. 4 is floor panel only with brick loadbearing walls. What is unique about these apartments is the marshalling of a steady flow of construction materials, and three fully manned construction work shifts. Table 6 is of interest in building statistical data on Soviet apartment construction.

Conclusions from the Ukraine

The report draws many conclusions from its experiences. The term "rapid construction" for instance, makes sense only for production line construction—construction with mechanized operations and the largest possible number of workers distributed on the site. Erection work for four section houses can be done in two parallel production lines with two tower cranes followed by four finishing work production lines. Materials and procedures that do not match the efficiency of industrialization are out—sand bases for concrete topping, wet plaster, roofing materials in rolls. And it takes the right equipment; the tower cranes used for panel erection are criticized as requiring too much time for installation, dismantling, and moving. Mobile revolving tower cranes are much more fitted to rapid construction.

According to the report, rapid construction requires pre-planning and close timing. All sub-grade work, construction roads, and

TABLE 6. DONETSK FIVE STORY APARTMENT HOUSES

Characteristic	Apartment Buildings: Donetsk No. 6	Donetsk No. 4	Donet-skzhils-troy No. 12	Makeev-zhils-troy No. 4
No. of floors	5	5	5	5
No. of sections	4	4	6	3
Net living space, m^2	1,839	1,851	3,800	1,402
Volume of structure, m^3	9,203	11,013	19,000	7,331
No. of apartments	58	60	120	45
m^2 net living space/apt.	31.7	30.8	31.7	
Construction time				
Below grade—days	16	26	13	41
Above ground—days	54	64	45	50
Total Working Days	70	90	58	91
Site labor, man-days/m^2 net living space				
Below grade	0.14	0.17	0.13	0.17
Erection	0.35	0.30	0.30	0.45
Finishing	1.87	1.70	1.54	1.8
Total	2.36	2.17	1.97	2.42
Yearly output of one tower crane—m^2 net living space	17,600	24,200	15,422	18,300

SOURCE: Rapid Construction of Apartment Houses in the Ukranian SSR, *1969*

approaches must be completed prior to precast structure erection. Materials have to be stocked at least two floors ahead of construction. Electric power, communications, and transportation equipment must be reliable, with job site reserves.

As a rule, Soviet precasting factories operate with little reserve storage in an attempt at perfect flow from production line conveyor belt to trailer to tower crane placement at the site. The report concludes that too often the obvious result is either too few or too many trailers at the site, and recommends immediate expansion of plant reserve storage.

The *Rapid Construction* report concludes that rapid construction does add to technical and economical levels of efficiency, that above ground erection time can be reduced 3 to 4 times over standard methods, and that net cost of construction is reduced by 4-5%. Labor consumption is reduced by 0.3-0.5 manday per m^2 of net living space. The report also concludes that with the number of buildings in simultaneous construction significantly decreased, reserves and tight spots in the industry as a whole will be more clearly revealed, and production planning will be much enhanced.

Commentary

The report on *Rapid Construction of Apartment Houses in the Ukrainian SSR* is an interesting treatise on how rapidly buildings can be erected with every production asset concentrated on single projects. It is admittedly apparent however that normal construction takes much longer. One evidence for this conclusion is the vast number of semi-erected or erected-but-unfinished buildings in each of the four largest cities of the USSR: Moscow, Leningrad, Kiev, and Tashkent—and with two or three idle tower cranes standing alongside each. Delays in construction are clearly attributable to shortages in the supply of panels, products, and fixtures from the factories, and shortages in labor. The Soviet construction industry is apparently pushed, or pushes itself, somewhat faster than it can produce, as something of a modus operandi and a stimulus for growth.

Construction for Seismic Loads

An additional area project of special interest is a 48 unit 4 story apartment house in Tashkent. The information was obtained from the Uzbek Republic Gosstroy and Glavtashkentstroy. As mentioned

TABLE 7. TASHKENT FOUR STORY APARTMENT HOUSE STANDARDS

APARTMENTS	48	
NET LIVING SPACE (LIVING AND BEDROOMS)	1481	m^2
NET LIVING SPACE, AVE. PER APT.	30.9	m^2
USEFUL LIVING SPACE (LIVING AND BED-ROOMS, ENTRY HALL, KITCHEN AND BATH)	2030	m^2
USEFUL LIVING SPACE, AVE. PER APT.	42.3	m^2
RATIO USEFUL/NET LIVING SPACE	1.37	
RATIO USEFUL/BUILDING GROSS AREA	Appx. .80	

64 METRIC TONS STEEL IN CONCRETE ABOVE GRADE FOR INTENSITY 8
119 METRIC TONS STEEL IN CONCRETE ABOVE GRADE FOR INTENSITY 9
40% MORE PANEL FAB-PLANT LABOR FOR INTENSITY 9 VS. MOSCOW (NON-SEISMIC)
24% MORE PANEL FAB-PLANT LABOR FOR INTENSITY 9 VS. INTENSITY 8
0.8 m^3 CONCRETE/m^2 NET LIVING SPACE ABOVE GRADE FOR SEISMIC 8
1.0 m^3 CONCRETE/m^2 NET LIVING SPACE ABOVE GRADE FOR SEISMIC 9

EXTERIOR PANELS 3.2 x 6 meters x 12 cm. 5.2 tons
CRANE REQUIREMENTS FOR ERECTION OF 96 APARTMENTS 45 days at 2 shifts/day
CRANE OPERATOR WAGES 125-150 rubles/month (35-hr. week)
CRANE RENTAL (incl. operator) 16 rubles/day—1st shift
11.2 " " —2nd shift
Negotiating —3rd shift

PANEL FACTORY AND TRANSPORT LABOR	1.61 man-days/m^2 net living space
SITE LABOR	2.09 " " " "
TOTAL LABOR	3.70 man-days/m^2 net living space

TRUCKING COST 5 kopecks/metric ton-km (average haul 10-12 km)
HAULING IS 3% OF TOTAL BUILDING COST
COST OF LOADING AT PANEL PLANT FOR 48 APARTMENTS 1800 rubles

COST OF 48 APARTMENTS WITH 1481 m^2 NET LIVING SPACE (2030 m^2 useful living space):

RUBLES	%	MAN-DAYS/m^2	NET LIVING SPACE
BELOW GRADE	19,200	12.5	0.30
ERECTION	73,000	47.7	0.58
PLUMBING	13,900	9.1	0.23
ELECTRICAL	4,700	3.1	0.20
COMMUNICATIONS	1,000	0.7	0.06
FINISHING	41,200	26.9	0.72
SUB-TOTAL	153,000	100.0	2.09
PANEL FABRICATION/TRANSPORT TOTAL FOR SEISMIC 9			1.61
(approx. equiv. Richter 12)			3.70

153,000/1481 103 rubles/m^2 net living space
153,000/2030 75 rubles/m^2 useful living space

SOURCE: UZBEK REPUBLIC GOSSTROY AND GLAVTASHKENTSTROY 4-5 September 1969

earlier, Tashkent is an extremely active seismic area; structures in Tashkent are heavily reinforced for lateral stresses. In the USSR Seismic Scale Intensity 7, 8, and 9 are approximately equivalent to Mercali Scale 7, 8, and 9; and Seismic Intensity 9 is approximately equal to Richter 12. Since the 1966 earthquake, Seismic 9 is the code standard for Tashkent construction.

With respect to foundation concrete:

> For buildings of no more than five stories no change is required in the amount of reinforcing steel used for various seismic zones as compared with nonseismic zones.


Leningrad: Panel Tractor-Trailer With Four Panels

For buildings above five stories, the USSR design adds 10% more steel for Intensity 6 relative to Intensity 5, 20% more for Intensity 7 relative to Intensity 5, and 50% more for Intensities 8 and 9 relative to Intensity 5. As a general rule for designing above Intensity 9, USSR design adds 50% more steel for the intensities above Intensity 9 to that required for Intensity 9.

With respect to the amount of steel reinforcing in concrete panel-type construction above grade:

Moscow is a nonseismic zone and requires 25 kg. steel/m^2 net living space. This amount is used through Intensity 6.

For each number on the seismic scale above Intensity 6, add 10-15 kg. steel/m^2 net living space for houses up to five stories.

In Sochi (the Crimea earthquake zone) the design for Intensity 7 uses 35 kg. steel/m^2 net living space, and the design for Intensity 8 uses 45-50 kg. steel/m^2 net living space.

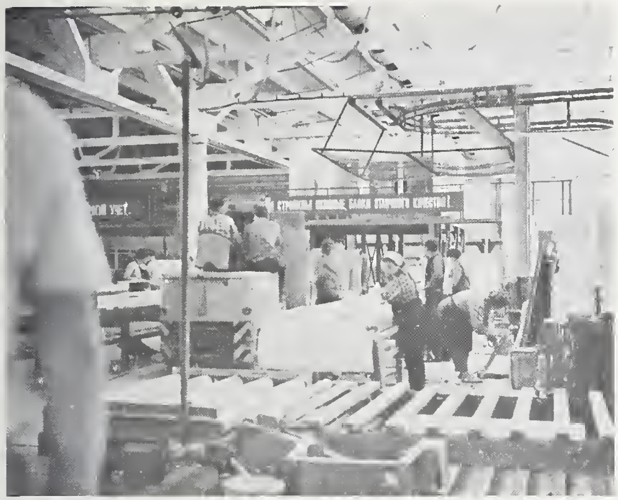
As a general rule, each unit of intensity (i.e. 8 vs. 7) costs an extra 4-5% in overall construction cost.

The Question of Quality

Quantity before Quality

Rapid transition from a rural to an urban population coupled with war destruction called for Herculean efforts to "build it now"—and the Soviets have done just that. The USSR has "built it now" in great quantity. People who lived in cabins or dilapidated buildings without electricity or water in the 1940's moved into apartments sharing bathrooms and kitchens with other families in the 1950's. In the 1960's these same families have moved up to their own new private quarters.

This astonishing pace of Soviet production has not been achieved without sacrifice in construction quality, esthetics, and well-planned community development. Apartment design philos-



Moscow's Window Factory: Glazing and Packaging

Window Sash Factory: Moscow

ophy has been dictated by the necessity of building square feet as rapidly as possible. Under this pressure the quality of construction has suffered.

Quality is a relative term. The observations made by the US delegation are relative to commonly accepted standards of US quality. It is a fair conclusion that if the US were building with as low a ratio of skilled craftsmen to million square feet of housing as is the USSR, there would be a serious lapse of quality in the US as well. Admiration for the success of the Soviet venture in building industrialization, in the face of tremendous difficulties, must nonetheless be tempered with difficult questions of quality.

Evidence

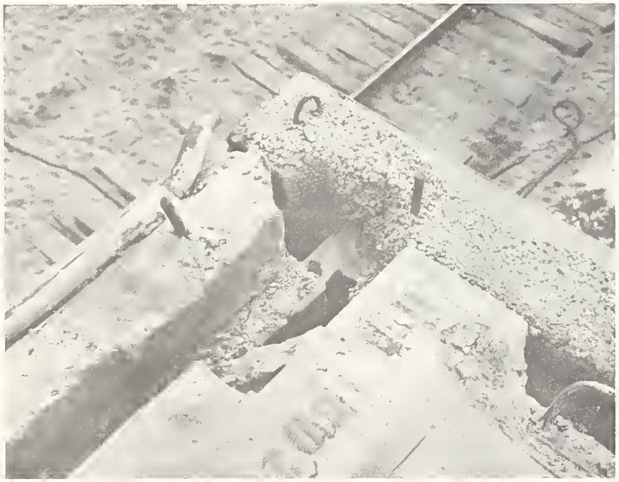
Panel casting in the plant is a beautifully sophisticated business, but by the time a panel is finally in place at the job site, any number of mishaps are probable. There is significant evidence of mishandling of green panels in the factory itself—chipping and gouging. Inverted steel channels used as bottom supports on which the panels rest vertically often do not have the wood blocking in place; the bottom of the panel is broken by the sharp channel edges. In some of the factories, a disproportionately large numbers of panels have rough or pocked surfaces. The ceramic tile veneer previously mentioned is a fine first step in giving life to standardized facades, but after banging around at the factory, enroute or on the job site many panels, perhaps most, have broken or missing tiles. Patching at the site is just not satisfactory. In apparent desperation many tile walls are painted, negating totally the good effects of a material supposedly maintenance free.

Panel jointing is another problem both inside and out. In many buildings the finished exterior joints are irregular and indecisive. Attempts at straightening or articulating the panels by painting on black stripes are esthetic disasters. Joints between interior panels are frequently uneven and gap as much as two inches apart—it is extremely difficult to patch this wide a joint prior to painting or papering.

Window sash and glass are frequently installed at the factory. Enroute and erection breakage and damage is not uncommon. Damage to door and window frames is typically repaired with

Leningrad: Placing Tiled Exterior Walls

Detail of Corner Connection and Floor Slab: Leningrad



heavy paint. After seeing the sags on the frames one delegate remarked, "It is impossible to put that much paint on." A few factories do an excellent job of in-plant spray paint finishing, but most on-site painting is consistently bad. Wall paper, the usual interior surface is also poorly applied—another delegate remarked, "Apparently the finish crew came on at midnight and there were no lights." The window sill detail for housing must be the cap-stone to this set of evidence. The standard sill cover is a thin, expensive, and unsightly piece of galvanized sheet metal usually bent out of shape, and in some instances quite pervious to water.

Given the above charges, one may question whether in the Soviet system there is an adequate authority matched with responsibility for quality control and inspection. The State Committee for Civil Construction and Architecture, Gosgrazdanstroy, a division of USSR Gosstroy, is responsible for overall USSR quality control, makes spot checks of the factories and construction sites, and has the authority to stop a factory or construction project if quality is too low. City Councils have local responsibility for inspection and quality control at factories and construction sites. Finally, each combine has a quality control group which reports to the plant manager.

The quality control problem may lie in a combination of these situations:

> The sale of a product or building is guaranteed; there are no competitors and costs will be paid.
>
> Bonuses are based solely on production.
>
> The combine erects as well as fabricates; there is no independent contractor to reject faulty material.
>
> The shortage of factory and construction workers, let alone skilled craftsmen, is acute.
>
> The priority list is topped by a demand for shelter now—quantity before quality.

Kiev Taxi Garage: Girder Beam Connection

Placing Fenestration: Leningrad

Soviet officials are reluctant to provide detailed information as to the extent of problems of quality and maintenance. There is however a free admission that there is need for greater concern and effort in these areas. It is clear that the building industry, having performed invaluable service to the country with a tremendous building program, is now under increasing pressure both from building users and from the Communist Party Central Committee to upgrade the quality of construction.

Part Seven
Economics and Industrialization

USSR and USA: The Cost of Housing

TABLE 8. RELATIVE COST BY CONSTRUCTION TYPE

	BOX	PANEL	BRICK
LABOR	15	20-25	20
MATERIAL	60	67	45
TRANSPORTATION AND EQUIPMENT	25	8-13	35
TOTAL COST	100%	100%	100%

TABLE 9. KIEV CHEAPEST APARTMENT SERIES UNIT COST

Living Rooms	People	Total Cost	Useful Living Space		Rubles Per m^2 Useful Living Space
1	2	2500 rubles	30 m^2	320 ft^2	83
2	3	3500	44	480	80
3	4-5	4500	55	600	82
4	5-6	5500	70	760	79

SOURCE: Ukraine SSR Gosstroy 1 September 1969

Unit Costs

Industrialization of the building process saves rubles for Russia. Although the figures are hardly precise, total unit costs for box and panel prefabrication are as much as 25% cheaper than brick and cast-in-place concrete. Relative proportions for labor, materials, and transportation and equipment are approximated in Table 8. The Labor category includes factory, transportation, and on-site labor. Panel construction for instance is approximately 50% factory and transportation labor and 50% site labor. Land, plant amortization, and profit are excluded as elements of these percentage costs.

Any of these figures should be used with caution if for no other reason than the obvious lack of a standard accounting base (are the windows and doors produced in-house, is below-grade work a purchased item or labor and materials?). There is no reason to assume a reversal of the trend to even greater savings with prefabrication. Boxes will probably become the most economical form of construction for housing, up to 10% cheaper than panels; but there is no unanimity on this point among plant managers and gosstroy executives. Full prefabrication of all housing is limited in planning only by an economical limit to transportation range on the order of 50-100 miles, and the speed with which new plants can be constructed to meet new building demands.

Table 9 lists unit costs for the cheapest series of apartments in Kiev. Table 10 lists these and other unit costs reported by other gosstroys. The figures for both tables exclude land, plant investment, interest, and heating plant for domestic and heating water normally provided as a city utility. It must be a constant point of reference that *net living space* refers only to living and bedrooms and *useful net living space* refers to living and bedrooms plus entry hall, kitchen, and bathroom. Throughout these tables useful living space is assumed to be 80% of gross building area.

It is interesting to note that Gosstroy representatives express serious concern over a decided trend to inflation in these building costs due to higher salaries and worker fringe benefits, and a demand by tenants for more amenities.

TABLE 10. APARTMENT HOUSE CONSTRUCTION UNIT COST

AVERAGE FOR WESTERN USSR	GROSS BLDG. AREA RUBLES PER m^2	NET LIVING SPACE RUBLES PER m^2
ACTUAL	170	94
GOAL	135	75
LENINGRAD		
FROM TABLE 2	130	72
STDRD BRICK BLDG.	160	88
KIEV		
FROM TABLES 3 AND 4, REGULAR	120-200	66-110
REGULAR AVE.	150	83
CHEAPEST AVE. FROM TABLE 9	118	65

TABLE 11. USSR AND US HAA HOUSING STANDARDS

Soviet Union Apartment Sizes (1)

Living (2) Rooms	Occupants	Useful Living Space (4) Sq. Ft.	Sq. Ft./Occ't
1	1-2	350	230
2	3	480	160
3	4-5 (3)	630	160
4	5-6 (3)	730	150

United States Apartment Sizes—
HAA Public Housing Standards (5)

		Useful Living Space (4)			
		Minimum (6)		Maximum	
Equiv. U.S. Unit	Occupants	Sq. Ft.	Sq. Ft./ Occ't	Sq. Ft.	Sq. Ft./ Occ't
Efficiency	1-2 (3)	280	280	400	400
1 bedroom	2	385	190	550	280
2 bedroom	3-4	510	150	720	210
3 bedroom	5-6	655	120	900	160

NOTES:
(1) Current Leningrad and Moscow standards. However, it appears that actual sizes areapproximately 10% less than this.
(2) Includes living room and bedrooms; excludes interior halls, kitchen, bathroom, and storage areas.
(3) Occasionally; area per person calculated using lower number of occupants. Where this superscript is not used the area per person is calculated using the midpoint of the number of occupants shown.
(4) Total area of apartment; USSR average from Tables 2, 4, and 9.
(5) FHA areas are 5-10% greater, depending on unit.
(6) Applicable several years ago, seldom used now.

Comparison: USSR and Western Europe

According to a 1962 report on Western European practice (*The Industrial Construction of Dwellings* by E. Fouque, a paper presented to the Institute of Structural Engineers, 1962), a sophisticated plant prefabrication and erection sequence using panel construction builds a 1,050 ft² dwelling unit in a large apartment building with an average 559 factory and 613 site manhours, including direct supervision but no indirect labor. This total of 1172 manhours per unit has been revised downward to 1,080 manhours according to J. Hosgel of the Portland Cement Association, based on detailed observations in Europe in 1969. He suggests a 5% figure for indirect labor for a total of 1130 manhours per 1,050 ft² apartment. This measure equals 2.6 mandays per m^2 of net living space, living and bedrooms only; the USSR averages 3.8 mandays per m^2 (Table 14). The Soviet practice has not yet reached the degree of efficiency attained by other European countries.

USSR Systems: Advantages and Disadvantages

What is the trend for Soviet unit costs? The industry has already received the ultimate in favored treatment: production is guaranteed, products are rigidly standardized with infrequent model changes, large production plants and massive construction complexes work the year round, and the industry is blessed by government with high priority labor allocation. With this series of preferred conditions, where is the room for improvement?

Two areas offer potential: first, material and skilled labor are so acute that for every construction job actually being worked, there are at least three or four unfiinished jobs standing idle; and second, the factory products are not yet first quality by Western standards—too much is wasted in reworking, site patching, and actual scrapping. With improving technology and expertise, unit costs will surely come down.

Housing Standards: USSR and USA

Area standards for USSR apartments are roughly equivalent to the minimums set by the US Housing Assistance Administration (HAA) for public housing several years ago (but seldom used now) and with fewer amenities (Table 11); and USSR housing standards apply to all but a tiny portion of the population. The average

net living space per Soviet is 7.4 m^2. The planning standard referred to above for new construction is just under 10 m^2. The 1985 Soviet goal is 15 m^2. To reach the 15 m^2 goal means increasing construction rates immediately by 70%; or put another way, means increasing the share of new housing from the current 25% to a projected 43% of total annual Soviet capital investment. Throw in only American public housing amenities and it means 50% of total Soviet capital investment, which is highly unlikely to say the least.

The Cost of USSR Methods for US Housing

There is considerable interest in the possibility of importing USSR methods for US low cost housing; an examination of the costs is in order. Tables 13 through 25 document costs for material, plant, and labor for USSR prefabrication and for conventional US building practice.

The conclusion is startling. The USSR system with materials and labor at US costs is more expensive than conventional US housing. A $13.70 per ft^2 US building would cost $17.70 constructed with the USSR system.

Table 13 sums the unit costs in using a USSR building system, on a typical US 9 story apartment house with 144 units. The data for the USSR systems costs are taken directly from official Soviet reports concerning several apartment houses built in 1968-1969. Data included plant and construction site manhours, and the quantities of materials required. The "total US cost of equivalent USSR items" is computed from this manhour and material data multiplied by current US labor rates and material costs. These "items" exclude land, financing and profit, all meaningless terms in the Soviet system.

Table 25 shows that 1969 US costs for conventional (non-industrialized) practice for the same buildling, but with superior quality and amenities, averaged $14.20 per ft^2 for "low cost" construction and $16.50 per ft^2 for average construction in 12 metropolitan areas of the US. These costs, like those above, excludes land, financing costs, and profit. The average for the entire US was approximately $1 less than the metropolitan figures, but metropolitan averages are used for comparison as they represent the more probable market for this type of housing.

For fair comparison the US "low cost" figure of $14.20 must be adjusted for the lesser quality and amendities in the very plain USSR apartments—closets, cabinets, light fixtures, etc. A rough approximation is $0.50 per ft^2 for this correction. The final comparison figures are $13.70 for the US, $17.70 for the USSR system in the US.

The major part of the $4.00 difference is labor, for the types and quantities of materials are essentially the same in both analyses. If the USSR figure of 3.8 mandays per m^2 could be lowered to the 2.6 of Western Europe, the difference would be reduced by $3.20 per $ft.^2$. The 5% professional fee would drop with the labor cost—another $.20 (.05 x $3.20). A third difference is in the capitalization of the prefabricating plant—$0.40 per ft^2. The three corrections together, $3.80 per ft^2, could essentially account for the $4.00 US-USSR difference.

TABLE 12. US AND USSR SYSTEMS COST COMPARISONS

USSR INDUSTRIALIZED CONSTRUCTION, EQUIVALENT USSR ITEMS AT US COST PER FT^2	$ 17.70
US CONVENTIONAL CONSTRUCTION, EQUIVALENT USSR ITEMS AT US COST PER FT^2	$ 13.70
US CONVENTIONAL CONSTRUCTION, HAA MIN STDRD ITEMS AT US COST PER FT^2	$ 14.20
FAMILY OF FOUR APT SIZE	
USSR CURRENT STRD—FT^2	630
USSR 1985 GOAL STRD—FT^2	950
HAA MIN STRD—FT^2	510
HAA MAX STRD—FT^2	720
US COST OF APT.* USING THE FOLLOWING:	
USSR INDUSTRIALIZED CONSTRUCTION & USSR CURRENT STRD 630 x $17.70	$11,200
USSR INDUSTRIALIZED CONSTRUCTION & USSR 1985 GOAL STRD 950 x $17.70	$16,800
US CONVENTIONAL CONSTRUCTION, USSR AMENITIES, HAA MIN STD 510 x $13.70	$ 7,000
US CONVENTIONAL CONSTRUCTION, USSR AMENITIES, HAA MAX STD 720 x $13.70	$ 9,900
US CONVENTIONAL CONSTRUCTION, HAA MIN STD 510 x $14.20	$ 7,200
US CONVENTIONAL CONSTRUCTION, HAA MAX STD. 720 x $14.20	$10,200

* *Note: Exclusive of proportionate share of public area of the apartment house which is the same for both USSR and US building design.*

TABLE 13. SUMMARY OF COSTS

TYPICAL USSR 9-STORY APARTMENT BUILDING BUILT IN U.S. USING USSR INDUSTRIALIZED PROCESS (PANELS), LABOR AND MATERIAL INPUT AT U.S. PRICES—144 UNITS & 97,000 FT^2 GROSS BUILDING AREA

Reference Table	Cost Items	Cost	Cost Per Unit	Cost per Ft^2
14	Factory and Site Labor	$ 892,000	$ 6,190	$ 9.20
15	Material			
	Architectural and Structural	387,000	2,690	4.00
16	Plumbing and Heating	132,000	920	1.30
17	Electrical	19,000	130	0.20
	Subtotal—Materials	$ 538,000	$ 3,740	$ 5.50
18	Equipment Rental	68,000	470	0.70
19	Supplemental Construction Cost	56,000	390	0.60
20	Panel Plant (excl. labor & material)	41,000	280	0.40
21	Landscaping and Walks	20,000	140	0.20
21	Parking *	18,000	130	0.20
	Architect-Engineer Fee @ 5% **	82,000	570	0.90
	Total U.S. Cost-Equiv. USSR Items	$1,715,000	$11,910	$17.70
22	Land	240,000	1,670	2.50
23	Financing	240,000	1,670	2.50
	Total U.S. Cost Before Profit	$2,195,000	$15,250	$22.70
	Profit at 5%	110,000	750	1.10
	Total U.S. Cost	$2,304,000	$16,000	$23.80

* *While parking areas are not part of USSR requirements, they are included herein for comparison of costs in this table with those of Table 25 (Costs for Conventional U. S. Practice) which include the cost of parking areas which are required in the U. S.*

** *Drawings and specifications are prepared and limited factory/site inspection is performed by the State (USSR), Republic or City Building Administration and are in addition to the above categories of charges. They are included herein at U.S. rates so that the "Total U.S. Cost-Equivalent USSR Items" will reflect a meaningful comparison with U.S. practice (Table 25).*

TABLE 14. FACTORY, TRANSPORT, AND SITE LABOR COST

TYPICAL 9-STORY APARTMENT BUILDING—144 UNITS & 97,000 FT² GROSS BUILDING AREA

LABOR CATEGORY	MAN-DAYS/m² NET LIVING SPACE *	TOTAL MAN-DAYS/BLDG **	AVERAGE LABOR RATE ($/HR) ***		LABOR COST PER BLDG. ($)
Factory Panel Fabrication Labor	1.50	7,620	4.95	39.60	302,000
Transport Labor	0.20	1,020	5.00	40.00	41,000
Site Construction Labor	2.11	10,720	6.40	51.20	549,000
TOTAL	3.81	19,360	5.75	46.00	892,000

Labor Cost Per Unit (144 Units) $6,190
Labor Cost Per Ft.² (97,000 Ft.²) $9.20

** These are the basic USSR Man-days expended for a similar building. Reference Tables 3, 4, 6, and 24.*
*** As per Table 4, building has 5,080 m² net living space. This equates to 9,030 m² gross building area = 97,000 ft².*
**** Reference Table 24.*

TABLE 15. MATERIAL COSTS: ARCHITECTURAL AND STRUCTURAL

TYPICAL 9-STORY APARTMENT BUILDING—144 UNITS & 97,000 FT² GROSS BUILDING AREA

		U. S. COSTS		
ARCHITECTURAL & STRUCTURAL MATERIAL	QUANTITY (METRIC)*	QUANTITY (U. S. EQUIVALENT)	UNIT COST ($)	TOTAL COST ($)
Wallpapered Surface	27,535 m²	296,400 Ft²	0.08	23,700
Painted Surface	5,140 m²	55,300 Ft²	0.04	2,200
Whitewashed Surface (Ceilings)	7,320 m²	78,800 Ft²	0.01	800
Roofing, Insulation, and Sheet Metal	1,299 m²	14,000 Ft²	0.40	5,600
Gypsum Concrete Partitions	6,971 m²	75,000 Ft²	0.40	30,000
Windows (including Glass)	776 m²	8,350 Ft²	3.	25,000
Doors, Trim and Finish Hardware	2,238 m²	24,100 Ft²	2.	48,200
Concrete Above Grade—Panels, Slabs, Stairs	3,618 m³	4,733 Yd³	12.30**	58,200
Reinforcing Steel in Concrete Above Grade	127,000 kg	280,000 Lbs	0.08	22,400
Concrete Below Grade	504 m³	660 Yd³	12.30**	8,100
Reinforcing Steel in Concrete Below Grade	15,000 kg	33,000 Lbs	0.08	2,600
Miscellaneous Steel (Rails, Balconies, Chutes, etc.)	37.8 Tons	41.7 Tons	700.	29,200
Elevators—Capacity 350 kg (770 lbs.)	4 Each	4 Each	10,000.	40,000
Floor Finishes (Wood, Parquet, Linoleum, Tile)	8,800 m²	95,000 Ft²	0.40	38,000
Tile on Exterior Walls	3,158 m²	34,000 Ft²	0.60	20,400
Cabinets—Counter Type	88 m	288 LF	28.	8,100
Cabinets—Overhead	132 m	432 LF	15.	6,500
Miscellaneous Supplies (5%)				18,000
TOTAL MATERIALS COST—ARCHITECTURAL AND STRUCTURAL				$387,000

Materials (A&S) Cost Per Unit (144 units) = $2,690

Materials (A&S) Cost Per Ft.² (97,000 Ft.²) = $4.00

** Reference Table 4*
*** Excluding reinforcing steel*

TABLE 16. MATERIAL COSTS: PLUMBING AND HEATING

TYPICAL 9-STORY APARTMENT BUILDING—144 UNITS AND 97,000 FT² GROSS BUILDING AREA

PLUMBING/ HEATING MATERIAL	QUANTITY (Metric)	QUANTITY (U.S. Equivalent)	U.S. COSTS UNIT COST ($)	U.S. COSTS TOTAL COST ($)
Bathtubs	144 Ea	144 Ea	42	6,000
Lavatories	144 Ea	144 Ea	23	3,300
Toilets	144 Ea	144 Ea	32	4,600
Kitchen Sinks	144 Ea	144 Ea	18	2,600
Piping (Plumbing)	4,400 M	14,500 LF	3	44,600
Radiators	832 M^2	8,952 Ft^2	0.76	6,800
Pumps	19 Ea	19 Ea	110	2,100
Piping (Heating)	6,400 M	21,000 LF	1.13	23,800
Instrumentation	LOT	LOT	7,500	7,500
Insulation	7,080 M	23,220 LF	0.73	16,900
Furnace*	1 Ea	1 Ea	10,000	10,000
Misc. Supplies (3%)				3,800
Total Materials Cost—Plumbing and Heating				$132,000
Materials Cost—Plumbing and Heating Per Unit (144 Units)				$ 920
Materials Cost—Plumbing and Heating Per Ft^2 (97,000 Ft^2)				$ 1.30

* *In USSR heat and domestic hot water are furnished by piping hot water from a municipal power plant, but this is not available in the U.S., and a furnace would be installed.*

TABLE 17. MATERIAL COSTS: ELECTRICAL

TYPICAL 9-STORY APARTMENT BUILDING—144 UNITS AND 97,000 FT² GROSS BUILDING AREA

ELECTRIC MATERIAL	QUANTITY (Metric)	QUANTITY (U.S. Equivalent)	U.S. COSTS UNIT COST ($)	U.S. COSTS TOTAL COST ($)
Switches	880 Ea	880 Ea	0.70	600
Receptacles	1,744 Ea	1,744 Ea	0.90	1,600
Ceiling Fixtures	880 Ea	880 Ea	3	2,600
Wire	41,200 M	135,000 LF	0.03	4,000
Switchgear and Panels	36 Ea	36 Ea	170	6,100
Distribution Feeders	4 Ea	4 Ea	800	3,200
Power Feeds (Elevators—Pumps)	8 Ea	8 Ea	50	400
Misc. Supplies (3%)				500
Total Materials Cost—Electrical				$19,000
Materials Cost—Electrical Per Unit (144 Units)				$ 130
Materials Cost—Electrical Per Ft^2 (97,000 Ft^2)				$ 0.20

TABLE 18. EQUIPMENT RENTAL COSTS

TYPICAL 9-STORY APARTMENT BUILDING—144 UNITS
AND 97,000 FT^2 GROSS BUILDING AREA

EQUIPMENT RENTED	QUANTITY	RENTAL PERIOD (Months)	U.S. COSTS RATE * ($/Month)	U.S. COSTS TOTAL COST ($)
Tower Cranes (5 Ton—70′ Boom)	2	2	1,450	5,800
Tractor and 20 Ton Semitrailer	2	2	2,860	11,400
Semitrailer Only	2	2	2,140	8,600
Front End Loader (2 CY)	1	2	1,800	3,600
Dump Trucks	2	1	850	1,700
Welding Machines	4	6	200	4,800
Air Compressors	2	6	400	4,800
Hand Tools	—	9	1,000	9,000
Scaffolding	2	9	250	4,500
Skip Hoists	2	9	300	5,400
Pickup Trucks	3	12	150	5,400
Miscellaneous Allowance				3,000
Total Equipment Rental Cost				$68,000
Equipment Rental Cost Per Unit (144 Units)				$ 470
Equipment Rental Cost Per Ft^2 (97,000 Ft^2)				$ 0.70

* *Estimated rates at 85% of Associated Equipment Distributors (AED) rates, excluding labor, plus allowance for fuel and maintenance supplies. Labor costs are part of overall labor cost in Table 14.*

TABLE 19. SUPPLEMENTAL CONSTRUCTION COSTS

TYPICAL 9-STORY APARTMENT BUILDING—144 UNITS
AND 97,000 FT^2 GROSS BUILDING AREA

1. Shift Differential—Allowance — $ 5,000
2. Spot Overtime—Premium @ 3% of Man-hours — 8,000
3. Subcontractors' Overhead @ 15% of Subcontractors' Labor & Materials Costs

Subcontractors	Labor Cost*	Material Cost**	Total
Below Grade	$ 35,100	$ 10,700	$ 45,800
Plumbing/Heating	61,000	132,000	193,000
Electrical	28,400	19,000	47,400
Total	$124,500	$161,700	$286,200

0.15 x $286,200 — 43,000

4. Total Supplemental Construction Cost — $56,000
5. Supplemental Cost Per Unit (144 Units) = $ 390
6. Supplemental Cost Per Ft^2 (97,000 Ft^2) = $ 0.60

* *Reference Table 24, labor costs per square meter net living space multiplied by 5,080 m^2 net living space.*

** *Reference Table 15 for below grade concrete and reinforcing steel; Table 16 for plumbing/heating cost; Table 17 for electrical cost.*

TABLE 20. ANNUAL PANEL PLANT COSTS EXCLUDING LABOR AND PRODUCTION MATERIALS

1. Investment required to produce 1,000 yd^3 of concrete per day (250,000 yd^3/yr, enough for approximately 7,500 apartment units per year)

a. Equipment	$ 5,290,000
b. Structures and Foundations	5,510,000
c. Land	500,000
Total Cost	$11,300,000

2. Annual Costs

a. Depreciation Expense—Equipment (15 years)	$ 350,000
b. Depreciation Expense—Structure (25 years)	220,000
c. Maintenance and Repair Materials ($1.50/$yd^3$)	380,000
d. Utilities and Fuel ($1.25/$yd^3$)	320,000
e. Interest at 10% (Average per year)	570,000
f. Taxes ($2.50/$100 of total cost)	280,000
g. Insurance	50,000
Total	$2,170,000

3. Cost per cubic yard of panels produced
   $2,170,000/250,000 yd^3/yr = $8.70/$yd^3$

4. Concrete panels, slabs, stairs per apartment building
   4,733 yd^3 panels (Table 15)
   $8.70 x 4,733 = $41,000

5. Concrete cost per apartment (144 units in building—Table 15)
   $41,000/144 = $280

6. Concrete cost per Ft^2 of apartment building (97,000 Ft^2—Table 15)
   $41,000/97,000 = $0.40

** The application of these costs to the typical 9-story apartment building is shown in Table 14 (Factory Panel Fabrication Labor) and Table 15 (Concrete Above Grade and Reinforcing Steel in Concrete Above Grade).*

SUMMARY ESTIMATE OF CAPITAL COST
USSR-DESIGNED CONCRETE PANEL PRECASTING PLANT BUILT IN U.S.
CAPACITY—1,000 YD^3/DAY, 250,000 YD^3/YEAR

DIRECT CONSTRUCTION COST	$6,710,000	
CONTRACTORS' OVERHEAD & PROFIT AT 15%	1,010,000	
TOTAL ESTIMATED CONSTRUCTION COST		$ 7,720,000
ENGINEERING (12 mos.)—8% OF CONSTRUCTION COST		620,000
INTEREST DURING CONSTRUCTION (8%, 1.5 YRS) $\frac{0.08 \times \$7{,}720{,}000 \times 1.5}{2} =$		460,000
INTEREST ON ENGINEERING COST $\frac{0.08 \times \$620{,}000}{2} + (0.08 \times \$620{,}000 \times 1.5) =$		100,000
SUBTOTAL		$ 8,900,000
START-UP COSTS		
Allow 100 man-months at $1,000/man-month		100,000
TOTAL BEFORE CONTINGENCY AND LAND		$ 9,000,000
CONTINGENCY ALLOWANCE—20%		1,800,000
TOTAL ESTIMATED COST (excluding Land)		$10,800,000
LAND COST		
Assume level, well-drained site that does not require pile foundations		
17 acres	$30,000	500,000
GRAND TOTAL		$11,300,000

TABLE 21. COSTS: LANDSCAPING, WALKS, AND PARKING

LANDSCAPING, WALKS AND PARKING
TYPICAL 9-STORY APARTMENT BUILDING—144 UNITS
& 97,000 FT² GROSS BUILDING AREA

A. Landscaping and Walks	$20,000	B. Parking 36,000 Ft² at $0.50	$18,000
Cost Per Unit (144 Units)	$ 140	Cost Per Unit (144 Units)	$ 130
Cost Per Ft² Building (97,000 Ft²)	$ 0.20	Cost Per Ft² Building (97,000 Ft²)	$ 0.20

TABLE 22. LAND COST

TYPICAL 9-STORY APARTMENT BUILDING—144 UNITS
& 97,000 FT² GROSS BUILDING AREA

1. Building Area—1,052 m² (Table 4)	11,300 Ft²	5. Typical Land Cost*	$ 4 per Ft²
2. Walks and green areas	11,700 Ft²	6. Total Land Cost	$240,000
3. Parking Area (1 Parking Place Per Unit)	36,000 Ft²	7. Cost Per Unit (144 Units)	$ 1,670
4. Total Area	59,000 Ft²	8. Cost Per Ft² Apartment Building (97,000 Ft²)	$ 2.50

* *Estimate is for low-rent district zoned for high-rise in U.S. metropolitan areas.*

TABLE 23. FINANCING COST ASSOCIATED WITH TYPICAL APARTMENT BUILDING

TYPICAL 9-STORY APARTMENT BUILDING—144 UNITS
& 97,000 FT² GROSS BUILDING AREA

INTERIM FINANCING (Construction Loan)	
Assumes:	
a. 100% financing ($2.3 million)	
b. Average amount of loan over the year is 50% of the $2.3 million required	
Interest and Points (14%) *	
0.14 x $1,150,000 =	$160,000
PERMANENT FINANCING FEE	
Permanent financing fee of 3.5% of total loan amount (FHA Insured Financing)	
0.035 x $2,300,000 =	80,000
TOTAL FINANCING COST	$240,000
Cost Per Unit (144 Units) = $1,670	
Cost Per Ft² (97,000 Ft²) = $2.50	

* *Interest and points for interim financing ranged from 12% on the West Coast (if money is available) to 13-15% in the Midwest and East. Information furnished by Lomas & Nettleton, mortgage bankers, San Francisco, Oct. 31, 1969.*

TABLE 24. US LABOR COSTS FOR EQUIVALENT USSR LABOR INPUT

This table is prepared to establish average U.S. man-hour and man-day costs for three categories of labor input which would be expended in fabricating panels for and constructing in the U.S. a typical USSR 9-story apartment building with 144 units and 5,080 square meters of net living space equivalent to 97,000 ft.[2] of gross building area. The three categories of labor input are fabricating plant, transport, and site construction labor.

1. Panel Fabricating Plant Labor
The labor input at the fabricating plant to manufacture panels is equivalent to 1.5 man-days per square meter of net living space for the typical apartment building (Table 3). This total includes all production and administration employees associated with the factory. For the U.S., an average hourly labor rate of $4.95 is based on the average gross pay in manufacturing for all full time employees (including management) for 1968 of $7,347 or $3.53 per hour, as reported in Facts For Bargaining, *Bureau of National Affairs, August 21, 1969. This rate was increased by 4% to $3.67 per hour to update it to 1969. To this was added fringe benefits at 25.5%* (Employee Benefits—1967, *U.S. Chamber of Commerce 1968), payroll taxes at 4.5% and insurance at 4.25%. Total additives were rounded to 35%, to yield a factory employee average total cost of $4.95 per hour.*
2. Transport Labor
The transportation labor cost estimate is based on 0.20 man-day per square meter of net living space (Table 3) for the typical apartment building. The hourly wage is the U.S. Department of Labor 30-city average reported in Building Construction Cost Data*—1969, published by R. S. Means Company, Inc. The rate reported includes fringe benefits; to this was added 4.5% for payroll taxes and 6% for insurance to arrive at a total rate of $5.00 per man-hour.*
3. Site Construction Labor
Tables 3, 4, and 6 have statistics for five large apartment buildings constructed in nonseismic zones in 1968-69 in the USSR. The reported consumption of on-site labor ranges from 1.825 to 2.36 man-days per square meter of net living space, with an average of 2.11 man-days per square meter of net living space. The 9-story apartment building referenced in Table 3 is the only one for which data were available on the breakdown of the total construction labor input into the various classifications such as erection labor, plumbing labor, electrical labor, etc. It is this breakdown in Table 3 which is used in Table 24 which follows to arrive at a weighted average U.S. hourly and daily labor rate applicable to the average total USSR construction labor input of 2.11 man-days per square meter of net living space for five apartment buildings. The hourly wage rates for the individual classifications are the "adjusted" U.S. Department of Labor 30-city averages reported in Building Construction Cost Data*—1969, published by R. S. Means Company, Inc. The rate reported includes fringe benefits; the "adjustments" add 4.5% for payroll taxes and 6% for insurance to arrive at the rates shown for the various labor classifications. The weighted average rate of $6.40 per man-hour for construction labor is used throughout the various analyses leading to the cost of using the USSR's industrialized building process in the U.S. and paying U.S. material and labor costs in the preceding tables.*

U. S. CONSTRUCTION LABOR COSTS FOR EQUIVALENT USSR LABOR INPUT TYPICAL USSR 9-STORY APARTMENT BUILDING

Classification of Construction Labor	Man-days/m² Net Living Space*	Average Labor Rate** ($/Hr)	Average Labor Rate** ($/Day)	Labor Cost/m² Net Living Space
Below Grade	0.13	6.60	52.80	$ 6.90
Erection	0.40	6.60	52.80	21.10
Plumbing and Heating	0.20	7.50	60.00	12.00
Electrical and Communication	0.10	7.00	56.00	5.60
Crane Operation	0.05	6.75	54.00	2.70
Elevator Installation	0.005	6.60	52.80	0.30
Finishing (Painters, Carpenters, Roofers)	0.90	5.95	47.60	42.80
Miscellaneous—helpers	0.004	5.05	40.40	0.20
Clerk of Works—foremen	0.028	6.95	55.60	1.60
Superintendent's Staff—helpers	0.008	5.05	40.40	0.30
Total and Weighted Average	1.825	$6.40	$51.20	$93.50

* *Reference Table 3 for construction labor input for typical 9-story apartment building.*
** *Includes fringe benefits, payroll taxes and insurance. Reference U.S. Dept. of Labor 30-city average reported in Building Construction Cost Data-1969, published by R S. Means Company, Inc. and adjusted to include 4.5% payroll taxes and 6% insurance.*

TABLE 25. CURRENT CONVENTIONAL US COSTS

TYPICAL LOW COST 9-STORY APARTMENT BUILDING BUILT IN U.S.

This table develops the U.S. unit costs for a Class B building (reinforced concrete frame and concrete or masonry floors and roof) built by normal U.S. construction practices, and having the same shape (number of stories and perimeter-to-area ratio) as the USSR typical building for which costs were analyzed in the preceding tables and summarized in Table 13. The unit costs in Table 13 are those which would be incurred if one were to build a typical USSR apartment building and use the USSR industrialized building systems (slabs and panels prefabricated in a factory) and consume the same amount of labor and material at U.S. costs. Under these conditions the USSR system would cost $16.80 per square foot exclusive of land and financing cost and profit. These items are excluded from the comparison because they are not items of cost in the USSR.

This table shows two sets of costs:

a. Class B—Average excludes built-in appliances, with amenities approximately the same as FHA 221(d)(3) quality. This is very superior to the USSR quality and amenities for which the Table 13 costs are shown. The current average cost for 12 metropolitan areas in the U.S. is $16.50 per square foot, exclusive of land and financing costs and profit. The average for the entire U.S. is only $15.50 per square foot.

b. Class B—Low Cost excludes built-in appliances, very plain, minimum uniform code, one bath per unit. This is the type of construction in the U.S. generally designated for "public housing"; it is superior in quality and amenities to that built in the USSR for all families—the typical apartment building analyzed in Table 13. The current average cost for Class B—Low Cost building in 12 metropolitan areas in the U.S. is $14.20 per square foot, exclusive of land and financing costs and profit. The average for the entire U.S. is only $13.20 per square foot.

c. It should be noted that the costs in Items a. and b. (1) represent superior quality and amenities relative to those in the USSR, and (2) are met in spite of a fragmented market with no guarantees as to annual production or sales.

UNIT CONSTRUCTION COST ESTIMATE IN UNITED STATES
CLASS B, AVERAGE—MARSHALL & STEVENS VALUATION METHOD

Type of Construction — Class B, Reinforced concrete frames and concrete or masonry floors and roofs; multiple-story apartment with elevator.

Quality of Construction — Average, excludes built-in appliances, amenities approximately the same as FHA 221(d)(3) quality.

Base Cost — Class B, Average = $15.67/ft.² (April, 1969). (Unit cost includes labor, materials, contractor's overhead and profit, architect-engineer fees, permits and miscellaneous costs. Unit cost excludes land and financing costs.)

Contractor's Profit — Assume at 5% of total cost

Adjustments to Average Base Cost

Structure height: Add 1% for each story over 3	1.06
Perimeter/Area multiplier: Area = 11,300 ft.² Perimeter = 730 LF	.980
For 9' floor-to-floor spacing	.971
Profit removal (5%)	= 1/1.05

Adjusted Ave. Base Cost = $15.67 x 1.06 x .980 x .971 x 1/1.05 = $15.10/ft²

Adjust Base Cost to Local Areas

Metropolitan Area	Adjusted Base Cost	Heating Factor	Local Area Multiplier	Current Cost Multiplier (Updated to Oct. '69	Local Area Unit Cost Per Ft.²
Atlanta, Georgia	$15.10	$ —.34	.94	1.03	$14.30
Boston, Mass.	15.10	+.38	1.08	1.03	17.20
Chicago, Illinois	15.10	+.38	1.10	1.02	17.40
Columbus, Ohio	15.10	+.38	1.06	1.02	16.70
Dallas, Texas	15.10	—.34	.99	1.02	14.90
Denver, Colorado	15.10	+.38	1.02	1.00	15.80
Los Angeles, Calif.	15.10	—.34	1.05	1.00	15.50
N.Y. City—Manhattan	15.10	+.38	1.21	1.03	19.30
N.Y. City—Excl. Manh'n.	15.10	+.38	1.11	1.03	17.70
Philadelphia, Pa.	15.10	+.38	1.05	1.03	16.70
San Francisco, Calif.	15.10	—.34	1.10	1.00	16.20
Seattle, Washington	15.10	.00	1.11	1.00	16.80
Average Current Cost For 12 Metropolitan Areas					$16.50

UNIT CONSTRUCTION COST ESTIMATE IN UNITED STATES
CLASS B, LOW-COST—MARSHALL & STEVENS VALUATION METHOD

Type of Construction — Class B, Reinforced concrete frames and concrete or masonry floors and roofs; multiple-story apartment with elevator.

Quality of Construction — Low Cost, very plain, minimum uniform code, one bath per unit.

Base Cost — Class B, Low Cost = $13.48/ft.² (April 1969). (Unit cost includes labor, materials, contractor's overhead and profit, architect-engineer fees, permits, and miscellaneous costs. Unit cost excludes land and financing costs.)

Contractor's Profit — Assume at 5% of total cost

Adjustments to Average Base Cost

Structure height: Add 1% for each story over 3	1.06
Perimeter/Area Multiplier: Area = 11,300 ft.² Perimeter = 730 LF	.980
For 9' floor-to-floor spacing	
Profit removal (assumed 5%)	= 1/1.05

Adjusted Ave. Base Cost = $13.48 X 1.06 X .980 X .971 X 1-.05 = $12.90/ft²

Adjust Base Cost to Local Areas

Metropolitan Area	Adjusted Base Cost	Heating Factor	Local Area Multiplier	Current Cost Multiplier (Updated to Oct. '69)	Local Area Unit Cost Per Ft.²
Atlanta, Georgia	$12.90	$ —.34	.94	1.03	$12.20
Boston, Mass.	12.90	+.38	1.08	1.03	14.80
Chicago, Illinois	12.90	+.38	1.10	1.02	14.90
Columbus, Ohio	12.90	+.38	1.06	1.02	14.40
Dallas, Texas	12.90	—.34	.99	1.02	12.70
Denver, Colorado	12.90	+.38	1.02	1.00	13.50
Los Angeles, Calif.	12.90	—.34	1.05	1.00	13.20
N.Y. City—Manhattan	12.90	+.38	1.21	1.03	16.60
N.Y. City—Excl. Manh'n.	12.90	+.38	1.11	1.03	15.20
Philadelphia, Pa.	12.90	+.38	1.05	1.03	14.40
San Francisco, Calif.	12.90	—.34	1.10	1.00	13.80
Seattle, Washington	12.90	.00	1.00	1.00	14.30
Average Current Cost for 12 Metropolitan Areas					$14.20

Analysis of the US Construction Industry

Consider the following:

According to *Engineering News Record,* 30 October 1969, physical output per construction worker has increased at an annual rate of only 0.4% over the last ten years compared with an increase at an annual rate of 2.5% for the total economy.

From the same reference, between 1945 and 1968, the homebuilding industry produced an annual average of 1.3 million dwelling units for the private market and 50,000 units of "public housing"; the industry built fewer than 2 million units in its most productive year of that period. The 1968 Housing and Urban Development Act established a 10-year goal of 26 million dwelling units, including 6 million subsidized units for low-and moderate-income families. This total of 2.6 million units per year is considered the minimum required to house the nation's population properly by 1979. With a normal curve of acceleration, the production rate must reach at least 3 million units per year toward the end of the 10-year period.

The number of skilled construction workers available for all current construction demands, industrial and non-industrial, is too small to handle even present needs; and this in spite of a recent history of record wages and wage increases, as well as cutbacks in federal construction.

There is a vast untapped reservoir of unskilled labor that can be trained far more quickly for jobs in the "industrialized building process"—plant production and erection—than in the conventional construction industry.

Current figures show that with prevailing costs of land, construction, interest and taxes, there is no chance of building a house or apartment at a cost within the means of a low-income family; and most, if not all, of the cost items are rising faster than the incomes of most low-income families.

Economic studies show that even with a 20% reduction in material and construction labor costs, the resultant reduction in monthly rent or purchase payments would be only 5%. The reason lies in the significant effect of interest, land, operating expense, and taxes on monthly installments. If housing for low-income families must be subsidized, it becomes imperative that the cost—and subsidy—be as low as possible.

Considering these facts, studies, problems, and realities; and considering the goals of the 1968 Housing and Urban Development Act . . . can the US building industry produce? Is it possible with conventional American construction to build the hopes and demands with which the 1968 goals are laced?

Extension of Industrialization to US Housing

The mobile home industry has rapidly expanded in recent years to produce transportable modules for permanent homes. These modules, complete with walls, floor, roof, piping, wiring, and fixtures, can be used singly or in combination on one, two, or three levels, depending on the size of the home or combination of homes desired. Modules are being built in sizes up to 12 x 60 ft and are generally of wood frame construction, occasionally steel or aluminum. Depending on the selling price, module size and highways, economic truck transport is possible up to 800 miles. The home owner or developer takes care of site purchase, foundations and steps, and occasionally a basement; after arrival of the modules, a local plumber and electrician make the necessary utility connections.

In certain areas of the US however there are problems with local codes and with the unwillingness of some unions to connect

Leningrad: Exterior Wall Panel Erection

Kiev: Plants are Generally Spacious and Spotless

utilities to a module built with either non-union labor or by "non-traditional" building unions in a factory. For single-family and low-rise buildings, the prefabricated building modules are now being sold for \$7-10 per ft² at the factory and \$10-12 per ft² installed, including all costs and profits, but not land. With carpentry, plumbing and electrical items largely installed under continuously productive conditions at the factory, there should not be a serious overall labor shortage, even with a multifold expansion of module production capability.

High-rise construction needs some form of structure with slots to house the lightweight modules, or prefabricated concrete panel or box systems. There will be labor shortages in many of the construction crafts if conventional cast-in-place concrete buildings are built in sufficient quantity to accommodate this in-city housing market.

The Western European systems are worth re-examination. Though this is not the report for detailed analysis, a few observations are in order:

Western European practices have cut combined factory and construction labor input per ft² of building to 70% of that required for the USSR, and can cut still more.

Western European prefabrication plants have lightweight machinery; some plants can be moved from construction site to construction site. Not all the plant needs indoor protection. These plants cost perhaps half that of USSR plants based on US costs.

Continued industrial improvements could bring US costs for box/panel systems in line with conventional construction. The first requirement is a metropolitan market large enough to sustain prefabrication plants of, say, 150,000-250,000 yds³ of product per year, or 4,000-7,000 HAA average size units.


Leningrad: Entry Detail

Several of the British, French, and Italian systems are being aggressively merchandized in the US; experienced US firms are signing up as licensees. Since these are strictly commercial arrangements there is every reason to believe that these or similar US systems will be competitive with traditional US high-rise low-cost housing.

Summary

Two projects, In-Cities Experimental Housing Research and Development and Operation Breakthrough, emphasize the US housing problem for the decade of the seventies. Industrialization of the building process will of necessity play a large role in the solution to this housing problem—to lowering construction costs, and to meeting the 1968 HUD goals. It is encouraging that a very large proportion of the more than 600 Operation Breakthrough proposals received in September 1969 are based on some form of industrialization.

It appears to some that a potential solution of housing the US population adequately by 1979 lies with prefabricated light-weight modules, and with rapid development of panel/box systems. Finally, industrialization will undobutedly have the beneficial effect of reducing the cost and construction time of conventional practice by forcing on it long overdue changes in restrictive codes and labor habits.

Commentary on the Soviet Experiment

The Industrialization Imperative for Housing

For the USSR the industrialized building process is a necessary response to an economic and urban phenomena reflecting an urgent need for mass housing—a need which can be met only by constructing large apartment building complexes. The low factory, housing, and skilled labor base from which the start has been made along with the relatively small number of skilled craftsmen required, and the fact that prefabricated concrete components make it possible to construct buildings with significantly less total labor input than would otherwise be required, make industrialization the answer to the Soviet problem. The trend of housing construction in the USSR has been impressive as to volume; the 1968 figure of 1.4 billion square feet total housing area compares favorably with the US construction of 1.5 billion square feet for the same period.

The industrialized building process in the USSR consists primarily of prefabrication for housing construction, and secondarily, of prefabrication for industrial and public buildings: factories, shops, offices, and schools. The housing segment of USSR industrialized building relates directly to its US counterpart and some direct economic comparisons are possible. With respect to other types of buildings, so much depends upon design and end use that a direct comparison of practices, labor costs, and material costs is not meaningful.

Process, Test-Bed, and Execution

Prefabricated elements for the building industry consist almost exclusively of precast concrete panels, boxes, trusses, beams, and volumetric crosses for seismic design. Plants for the manufacture of the precast pieces are located throughout the entire country. The concept or "process" of the industrialized building system has been well thought out in the USSR, and the regimented, huge, and guaranteed Soviet market is the perfect "test-bed." The USSR has simplified the construction process by reducing the number of alternatives. However, "execution" in design flexibility, the joining of plant production to site erection, and reasonable construction quality has not been accomplished. It is quite probable that the next ten years will see a decided improvement in these areas.

The Unofficial Record

The Soviets are research-minded and are advancing building technology. That they can manufacture concrete components with efficiency and effectiveness is amply demonstrated in the factories. Combined factory and construction labor savings are claimed to be 40-50%, and this is probably true. They can erect prefabricated units with considerable speed, 30-45% faster than conventional brick construction.

The Soviets can build economically, but the relative cost is higher than for comparable construction in the US, and the US construction has better quality and more amenities. However, for the Soviets, the trend toward industrialization has lowered costs and enabled all-weather construction.

Plans for typical dwellings are questionable. It is understandable that economy dictates small rooms, but neither standardization nor technology should impose upon users and architects the unreasonable requirement that living rooms should be the same size as bedrooms, or that dwellings must be chopped up like egg crates. There are, however, promising design directions. The Soviets, in addition to starting catalog systems, are working with the idea of dwelling-size structural modules which the architect, and more important, the tenant, can subdivide into smaller spaces of varying sizes to meet specific family needs.

The Soviets can handle big things with a high degree of effectiveness; manufacturing large boxes and stacking them 20 or 30 stories high is no problem. But details such as window sills and floor-wall-ceiling connections, finishing, and integration of wiring, heating, and plumbing are crudely handled. Such matters are either beyond the ability of the Soviets, or beyond their immediate valued interest, or perhaps beyond both.

From the standpoint of architectural quality, the factories are excellent and the "unique" buildings are often quite good. But the architectural quality of housing is poor. In the Soviet Union, process is better than product; the factories which make the houses are finer than the houses.

The Job Remaining

The Soviets recognize these problems. At the last wrap-up meeting in the main office of USSR Gosstroy, the presiding official said, "Where there are too many buildings of the same type there is monotony. It is the government decision to provide more factories which will be more flexible—to manufacture buildings of different types. Another target is to create factories to build components which are interchangeable with the components manufactured by other factories. We want to design houses making use of a catalog of components which will allow us to give our people dwellings that vary in size, height, and character." There seems to be an innate desire toward individualism despite the standardization and regimentation of this crash building program in the Soviet Union. This desire is evident when tenants rearrange and decorate their balconies; when either a group of tenants or the architects decide on different colors for the end walls of the same type houses in one district; when the tenant moves in and changes the wallpaper; and when one official in the Ukraine says, "We want Kiev to be Kiev."

TABLE 26. CONVERSION FACTORS

1 ft	= 0.305 m	= 30.48 cm	
1 m	= 39.4 in	= 3.28 ft	= 1.1 yd
1 cm	= 0.39 in	= 0.033 ft	= 0.011 yd
1 m^2	= 10.8 ft^2	= 1.20 yd^2	
1 ft^2	= 0.09 m^2	= 0.11 yd^2	
1 yd^2	= 0.84 m^2	= 9.0 ft^2	
1 m^3	= 35.3 ft^3	= 1.31 yd^3	
1 yd^3	= 27.0 ft^3	= 0.76 m^3	

1 hectare = 2.5 acres = 10,000 m^2
1 ruble = $1.10

CREDITS

Editing	Chalmers G. Long, Jr.
Graphics Advisor	Peter C. Papademetriou
Production	Peter G. Rowe

final production of this publication was executed by the Office of Technical Information and Publications, National Bureau of Standards

Latest developments in the subject area of this publication, as well as in other areas where the National Bureau of Standards is active, are reported in the NBS Technical News Bulletin. See following page.

HOW TO KEEP ABREAST OF NBS ACTIVITIES

Your purchase of this publication indicates an interest in the research, development, technology, or service activities of the National Bureau of Standards.

The best source of current awareness in your specific area, as well as in other NBS programs of possible interest, is the TECHNICAL NEWS BULLETIN, a monthly magazine designed for engineers, chemists, physicists, research and product development managers, librarians, and company executives.

If you do not now receive the TECHNICAL NEWS BULLETIN and would like to subscribe, and/or to review some recent issues, please fill out and return the form below.

(cut here)

Mail to: Office of Technical Information and Publications
National Bureau of Standards
Washington, D. C. 20234

Name ______________________

Affiliation ______________________

Address ______________________

City ____________ State ________ Zip ________

☐ Please send complimentary past issues of the Technical News Bulletin.

☐ Please enter my 1-yr subscription. Enclosed is my check or money order for $3.00 (additional $1.00 for foreign mailing).
Check is made payable to: SUPERINTENDENT OF DOCUMENTS.

NBS Spec. Publ. 334

U.S. DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20230

OFFICIAL BUSINESS

PENALTY FOR PRIVATE USE, $300

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF COMMERCE